COLLEGE OF ENGINEERING

ADMINISTRATION

W. Kent Fuchs, dean

David Gries, associate dean for undergraduate programs

Christopher K. Ober, associate dean for research and graduate studies

TBA, associate dean for diversity

Deborah Cox, assistant dean for strategic planning, assessment, and new initiatives

Betsy East, assistant dean for student services

Cathy Long, assistant dean for administration

Tim Dougherty, assistant dean for alumni affairs and development

FACILITIES AND SPECIAL PROGRAMS

Most of the academic units of the College of Engineering are on the Joseph N. Pew, Jr. Engineering Quadrangle. The School of Applied and Engineering Physics is located in Clark Hall on the College of Arts and Sciences campus, and the Department of Biological and Environmental Engineering is in Riley-Robb Hall on the campus of the New York State College of Agriculture and Life Sciences.

Special university and college facilities augment the laboratories operated by the various engineering schools and departments, and special centers and programs contribute to opportunities for study and research.

Cornell programs and centers of interest in engineering include the following:

Center for Applied Mathematics. This cross-disciplinary center administers a graduate program.

Center for Nanoscale Systems. The mission of this National Science Foundation Nanoscience and Technology Center is to develop innovative nanoscale systems to revolutionize information technology and to further nanoscience technology. The facilities for this center are distributed between Clark Hall and the Engineering Quadrangle, and especially in Duffield Hall.

Center for Radiophysics and Space Research. This interdisciplinary unit facilitates research in astronomy and the space sciences.

Cornell Theory Center. A supercomputer facility used for advanced research in engineering and the physical and biological sciences.

Cornell High Energy Synchrotron Source (CHESS). A high-energy synchrotron radiation laboratory operated in conjunction with the university's high-energy storage ring. Current research programs at CHESS are in areas of structural biology, chemistry, materials science, and physics.

Cornell Nanoscale Science and Technology Facility (part of the National Science Foundation–funded National Nanofabrication Users Network). This center provides equipment and services for research in the science, engineering, and technology of nanometer-scale structures for electronic, chemical, physical, and biological applications.

Cornell Waste Management Institute. This research, teaching, and extension program within the Center for Environmental Research addresses the environmental, technical, and economic issues associated with solid waste.

Institute for the Study of the Continents. This interdisciplinary organization promotes research in deep seismic exploration of the structure, composition, and evolution of the continents.

W. M. Keck Foundation in Nanobiotechnology. Facilities of this program include tools for nanoscale diagnostics of biomaterials.

Laboratory of Plasma Studies. A center for research in plasma physics.

Cornell Center for Materials Research. An interdisciplinary center, with substantial support from the National Science Foundation, that performs state-of-the-art materials research and provides sophisticated scientific measurement and characterization equipment.

National Astronomy and Ionosphere Center. The world's largest radio-radar telescope facility, operated by Cornell in Arecibo, Puerto Rico.

Multidisciplinary Center for Earthquake Engineering Research. A facility established by the National Science Foundation and a group of universities to study response and design of structures in earthquake environments.

Nanobiotechnology Center. The mission of this National Science Foundation Science and Technology Center is to develop nanoscale technologies and science applied to the life sciences. The facilities of this center are distributed between Clark Hall and Duffield Hall.

National Institutes of Health/National Science Foundation Developmental Resource in Biophysical Imaging and Optoelectronics. This resource develops novel measurement and optical instrumentation for solving biophysical problems.

Network for Earthquake Engineering Simulation (NEES). A system of nationwide experimental facilities linked by high-performance Internet for laboratory and computational simulation of structures under earthquake loads.

Power Systems Engineering Research Center. A National Science Foundation cooperative center between university and industry in which research is centered on power systems and infrastructure networks.

Program of Computer Graphics. This interdisciplinary research center operates one of the most advanced computer-graphics laboratories in the United States.

Program on Science, Technology, and Society. This cross-disciplinary unit sponsors courses and promotes research on the interaction of science, technology, and society.

Alliance for Nanomedical Technologies. The alliance brings together collaborative teams of academic scientists and industrial affiliates to explore the design and fabrication of novel nanomedical devices.

The programs listed above are sponsored by College of Engineering units, and several are industry affiliated.

DEGREE PROGRAMS

Cornell programs in engineering and applied science lead to the degrees of bachelor of science (B.S.), master of engineering (with field designation) (M.Eng.), master of science (M.S.), and doctor of philosophy (Ph.D.).

General academic information concerning the B.S. degree is given below under "Undergraduate Study." The student pursues the degree in one of 13 majors. The majors are described under "Engineering Majors."

Many students stay a fifth year in the College of Engineering to pursue a professional degree, the master of engineering (M.Eng.) degree. Joint enrollment in the B.S. and M.Eng. degrees is possible for students in their last semester who lack only 1 to 8 credits for the B.S.

M.Eng. degrees are awarded in most of the major areas. In addition, the following M.Eng. degrees are awarded: aerospace engineering, biomedical engineering, electrical engineering, engineering mechanics, nuclear engineering, operations research and industrial engineering, and systems engineering. For full details on M.Eng. degrees, see "Master of Engineering Degree Programs."

Programs leading to the M.S. and Ph.D. degrees are administered by the Graduate School. They are described in the *Announcement of the Graduate School* and the special announcement *Graduate Study in Engineering and Applied Science.*

UNDERGRADUATE STUDY

Students in the College of Engineering spend most of their first two years of undergraduate studies in the Common Curriculum, which is administered by the College Curriculum Governing Board (CCGB) through the associate dean for undergraduate programs and Engineering Advising. At the end of their third semester, they affiliate with one of these majors:*

biological engineering (BE)†

chemical engineering (ChemE)

civil engineering (CE)

computer science (CS)

electrical and computer engineering (ECE)

engineering physics (EP)

environmental engineering (EnvE)

independent major (IM)

information science, systems, and technology (ISST)—with options in information science and management science

materials science and engineering (MS&E)

mechanical engineering (ME)

operations research and engineering (ORE)

science of earth systems (SES)

Criteria for affiliation with the majors are described under "Affiliation with a Major." The majors are described under "Undergraduate Engineering Majors."

Most of the majors have a corresponding minor, in which the student can pursue a secondary interest. In addition, there are minors in applied mathematics, biomedical engineering, civil infrastructure, engineering management, engineering statistics, game design, industrial systems and information technology, and information science. See the main section, "Engineering Minors."

*The majors biological engineering, chemical engineering, civil engineering, electrical and computer engineering, materials science and engineering, and mechanical engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

†To major in biological engineering, students normally enroll in the College of Agriculture and Life Sciences for the first three years and jointly in that college and the College of Engineering for the final year. However, students initially enrolled in the College of Engineering may affiliate with the biological engineering major and complete the degree solely within Engineering.

There is no undergraduate major in nuclear science and engineering. Students who intend to enter graduate programs in this area are encouraged to begin specialization at the undergraduate level. This may be done by choice of electives within the major (e.g., engineering physics, materials science and engineering, civil engineering, chemical engineering, and the independent major). Contact a faculty member in the graduate field of nuclear science and engineering who is most directly concerned with the curriculum, including K. B. Cady, D. A. Hammer, R. W. Kay, and V. O. Kostroun.

Graduation Requirements

To receive the bachelor of science degree, students must meet the requirements of the common curriculum (outlined below) as set forth by the College of Engineering, including the requirements of their chosen major, as established by the school or department that administers the major. (Further explanation of the revised common curriculum and major flow charts are provided in the 2007–2008 edition of the *Engineering Undergraduate Handbook.*)

Course Category	*Credits*
1. Mathematics (major-specific)	15–16
2. Physics (major-specific)	8–12
3. Chemistry (major-specific)	4–8
4. First-year writing seminar	6
5. Technical writing*	3
6. Computing	5
7. Introduction to engineering (ENGRI)	3
8. Two engineering distributions (ENGRD)	6–8
9. Liberal studies distribution (6 courses min.)	≥ 18
10. Advisor-approved electives	6
11. Major program	
a. Major-required courses	≥ 30
b. Major-approved electives	9
c. Courses outside the major	9
12. Two semesters of physical education in the freshman year and demonstration of proficiency in swimming (university requirement)	

From 124 to 134 credits are required for graduation, depending on the major (see "Engineering Majors").

*Technical-writing courses may simultaneously fulfill another requirement.

Mathematics

The normal program in mathematics includes MATH 191, 192, 293 or 294 (depending on the major), and a major-specific math course. At least C– must be attained in these courses; if not, the course must be repeated immediately before the next course in the sequence is taken. Failure to achieve at least C– the second time will generally result in withdrawal from the College of Engineering. Courses that are taken a second time to meet this or any requirement do not yield additional credit toward a degree.

Physics

The normal program in physics includes PHYS 112, 213, and 214 or the corresponding honors courses (PHYS 116, 217, and 218). Engineering students must attain at least C– in each math prerequisite of a physics course before taking the physics course (e.g., C– in MATH 191 before taking PHYS 112 and C– in MATH 192 before taking PHYS 213). The following substitutions are allowed for PHYS 214: ChemE, CE, CS, ISST, and SES majors: CHEM 208. BE and EnvE majors: CHEM 257 or 357. ORE majors: CHEM 208, CS 280, or MATH 304, 311, or 336.

Chemistry

CHEM 209 is required. The content is the same as that of CHEM 207, but Engineering students are expected to take 209.

Typically, CHEM 209 is taken during the freshman year, but students who wish to complete the physics program (PHYS 112, 213, and 214) first may postpone CHEM 209 until the sophomore year.

Students considering chemical engineering must take CHEM 209 in the fall of their freshman year and CHEM 208 in the spring semester. Students considering the geological sciences major or a health-related career such as medicine should take the CHEM 209–208 sequence.

Computing

Students learn about computing using two programming languages by taking one of two sequences: (1) CS 100J and CS 101M or (2) CS 100M (BE majors make take BEE 151 instead) and CS 101J. The first course is taken in the first year. The second course, a 1-credit S-U course, is taken as soon as possible thereafter but no later than the fourth semester.

First-Year Writing Seminars

Each semester of their freshman year, students choose a first-year writing seminar from over 100 courses offered by over 30 different departments in the humanities, social sciences, and expressive arts. These courses offer the student practice in writing English prose. They also assure beginning students the benefits of a small class.

Technical Writing

Students can fulfill the upper-level technical-writing requirement using one of the six alternatives below. See www.engineering.cornell.edu/ECP/ for more information.

1. ENGRC 350 or 335
2. The Writing-Intensive Co-op—an opportunity to combine work and academics. Some co-op students do a significant amount of writing on the job; under certain circumstances, this writing will satisfy the technical-writing requirement.
3. An officially designated Writing-Intensive (W-I) engineering course:
   - ENGRD/A&EP 264
   - CHEME 432
   - MS&E 403 and 404 (both)
   - MS&E 405 and 406 (both)
   - M&AE 427
   - BEE 450 with co-registration in BEE 493
   - BEE 473 with co-registration in BEE 493
   - BEE 489
4. ENGRC 302, a 1-credit attachment to an engineering course that is not one of the officially designated W-I courses (see #3 above). An instructor may wish to extend the writing in their course for a given semester so that it will fulfill the technical-writing requirement. With the approval of the CCGB's Subcommittee on Technical Writing, the instructor may have students co-register in ENGRC 302, which may be taken more than once with different courses by permission of the engineering instructor.
5. COMM 260, 263, or 352, taught by the Department of Communication (in the College of Agriculture and Life Sciences).
6. Petition. Occasionally, a student will be doing a significant amount and variety of technical writing elsewhere in the College of Engineering. It may be appropriate to petition the CCGB's Subcommittee on Technical Writing for permission to use this forthcoming writing (not past writing) to meet the technical-writing requirement.

Introduction-to-Engineering Course

An introduction-to-engineering course (designated ENGRI) must be taken during the freshman year. This course introduces students to the engineering process and provides a substantive experience in an open-ended problem-solving context. See the Introduction-to-Engineering course listing for current course offerings.

Engineering Distribution

Two engineering distribution (ENGRD) courses (6–8 credits) must be selected from two different categories listed below. A student may use any one of the possible substitutions described.

1. *Scientific computing*

   ENGRD 320 Computers and Programming

   ENGRD 340 Engineering Computation

   ENGRD 321 Numerical Methods in Computational Molecular Biology

   ENGRD 322 Introduction to Scientific Computation

2. *Materials science*

   ENGRD 261 Introduction to Mechanical Properties of Materials: From Nanodevices to Superstructures

   ENGRD 262 Electronic Materials for the Information Age

3. *Mechanics*

   ENGRD 202 Mechanics of Solids

   ENGRD 203 Dynamics

   Majors in Engineering Physics may substitute A&EP 333 for ENGRD 203.

4. *Probability and statistics*

   ENGRD 270 Basic Engineering Probability and Statistics

   Majors in Electrical and Computer Engineering may substitute ECE 310 for ENGRD 270. Majors in Engineering Physics may substitute ECE 310 or MATH 471 for ENGRD 270. Majors in Civil Engineering, Biological Engineering, and Environmental Engineering may substitute CEE 304 for ENGRD 270.

5. *Electrical sciences*

   ENGRD 210 Introduction to Circuits for Electrical and Computer Engineers

   ENGRD 230 Introduction to Digital Logic Design

   ENGRD 264 Computer-Instrumentation Design

6. *Thermodynamics and energy balances*

   ENGRD 219 Mass and Energy Balances

   ENGRD 221 Thermodynamics

7. *Earth and life sciences*

   ENGRD 201 Introduction to the Physics and Chemistry of the Earth

   ENGRD 251 Engineering for a Sustainable Society

   ENGRD 260 Principles of Biological Engineering

8. *Biology and chemistry*

   ENGRD 252/A&EP 252 The Physics of Life

   BIO G 101 and 103 Biological Sciences, Lec and Lab

   BIO G 105 Introductory Biology

   BIO G 107 General Biology (summer only)

   CHEM 389 Physical Chemistry I

Some majors require a specific engineering distribution course as a prerequisite for the upper-class course sequence. These requirements are as follows:

Biological Engineering: ENGRD 202

Chemical Engineering: ENGRD 219

Civil Engineering: ENGRD 202

Computer Science: ENGRD 211 (co-enrollment in CS 212 highly recommended)

Electrical and Computer Engineering: ENGRD 230

Environmental Engineering: ENGRD 202

Geological Sciences: ENGRD 201

Information Science, Systems, and Technology: ENGRD 270

Materials Science and Engineering: ENGRD 261 or ENGRD 262

Mechanical Engineering: ENGRD 202

Operations Research and Engineering: ENGRD 270

Some majors require additional distribution courses after affiliation.

Liberal Studies Distribution

Global and diverse societies require that engineers have an awareness of historical patterns, an appreciation for different cultures, professional ethics, the ability to work in multifaceted groups, and superior communications skills. Cornell has a rich curriculum in the humanities, arts, and social sciences, enabling every engineering student to obtain a truly liberal education. At least six courses (totaling at least 18 credits) are required, and they should be chosen with as much care and foresight as courses from technical areas.

- The six courses must be chosen from at least three of the following six groups.
- At least two of the six courses must be at the 200 level or higher.

Besides courses classified as liberal studies distribution in Arts and Sciences, Engineering classifies appropriate courses in other colleges as meeting the various categories. To view these courses, visit www.engineering.cornell.edu/student-services/academic-advising/index.cfm, which contains a complete listing of acceptable courses in each group. A list of courses is also available in Engineering Advising, 167 Olin Hall.

Group 1. Cultural Analysis (CA)

Courses in this area study human life in particular cultural contexts through interpretive analysis of individual behavior, discourse, and social practice. Topics include belief systems (science, medicine, religion), expressive arts and symbolic behavior (visual arts, performance, poetry, myth, narrative, ritual), identity (nationality, race, ethnicity, gender, sexuality), social groups and institutions (family, market, community), and power and politics (states, colonialism, inequality).

Group 2. Historical Analysis (HA)

Courses in this group interpret continuities and changes—political, social, economic, diplomatic, religious, intellectual, artistic, and scientific—through time. The focus may be on groups of people, dominant or subaltern, a specific country or region, an event, a process, or a time period.

Group 3. Literature and the Arts (LA)

Offerings in this area explore literature and the arts in two different but related ways. Some courses focus on the critical study of artworks and on their history, aesthetics, and theory. These courses develop skills of reading, observing, and hearing and encourage reflection on such experiences; many investigate the interplay among individual achievement, artistic tradition, and historical context. Other courses are devoted to the production and performance of artworks (in creative writing, performing arts, and media such as film and video). These courses emphasize the interaction among technical mastery, cognitive knowledge, and creative imagination.

Group 4. Knowledge, Cognition, and Moral Reasoning (KCM)

Offerings in this area investigate the bases of human knowledge in its broadest sense, ranging from cognitive faculties shared by humans and animals such as perception, to abstract reasoning, to the ability to form and justify moral judgments. Courses investigating the sources, structure, and limits of cognition may use the methodologies of science, cognitive psychology, linguistics, or philosophy. Courses focusing on moral reasoning explore ways of reflecting on ethical questions that concern the nature of justice, the good life, or human values in general.

Group 5. Social and Behavioral Analysis (SBA)

Courses in this area examine human life in its social context through the use of social-scientific methods, often including hypothesis testing, scientific sampling techniques, and statistical analysis. Topics studied range from the thoughts, feelings, beliefs, and attitudes of individuals to interpersonal relations between individuals (e.g., in friendship, love, conflict) to larger social organizations (e.g., the family, society, religious or educational or civic institutions, the economy, government) to the relationships and conflicts among groups or individuals (e.g., discrimination, inequality, prejudice, stigmas, conflict resolution).

Group 6. Foreign Languages (not literature courses)

Courses in this area teach language skills, inclusive of reading, writing, listening, and spoken non-English languages, at beginning to advanced levels.

Electives

- **Advisor-approved electives:** 6 credits required (approved by the academic advisor). Because these courses should help develop and broaden the skills of the engineer, advisors generally accept the following as approved electives:

1. One introduction-to-engineering course (ENGRI)
2. Engineering distribution courses
3. Courses stressing written or oral communication
4. Upper-level engineering courses
5. Advanced courses in mathematics
6. Rigorous courses in the biological and physical sciences
7. Courses in business, economics, or language (when they serve the student's educational and academic objectives)
8. Courses that expand the major or another part of the curriculum.

9. Up to 6 credits of advisor-approved electives may come from ROTC courses at the 300 level or higher.

- **Major-approved electives:** 9 credits (approved by the major and faculty advisors in the major). Refer to the major curricula for descriptions of courses in this category.
- **Outside-the-major electives:** 9 credits of courses outside the major to ensure breadth of engineering studies

Social Issues of Technology

It is important for engineers to realize the social and ethical implications of their work. Consequently, in selecting their liberal studies distribution courses and approved electives, students are urged to consider courses listed in the "Science and Technology Studies" undergraduate area of concentration (see "Interdisciplinary Centers and Programs"). These courses may provide students with important perspectives on their studies and their future careers.

Engineering Advising

Entering first-year students are assigned a faculty advisor (who may or may not be in their intended major), who remains their advisor until affiliation with a major (normally during the fourth semester). The students are also under the administration of Engineering Advising in Olin Hall, which implements the academic policies of the College Curriculum Governing Board. Engineering Advising serves as the primary resource center for undergraduate students in the college, offering general advising and counseling. Other student services offices located in Olin Hall are Engineering Learning Initiatives and Diversity Programs in Engineering (DPE), which are primary resources for counseling, support, tutoring, and networking opportunities.

First-Year Requirements

During the first year, engineering students are expected to complete (or receive credit for) the following core requirements:

- MATH 191 and 192
- Two of: CHEM 209, 208, PHYS 112, 213, 214* (or the Honors equivalent)
- CS 100
- Two first-year writing seminars
- One introduction to engineering (ENGRI) course
- Two physical education courses

*Students with an interest in pre-med (or other health-related careers), chemical engineering, or the science-of-earth-systems option in geological sciences should enroll in the CHEM 209–208 sequence during their first year.

Affiliation with a Major

Students must apply for affiliation with a major during the first semester of their sophomore year, although earlier affiliation may be granted at the discretion of the major. This is done by visiting the undergraduate major office and completing the application for major affiliation form. To affiliate, students must (1) make good progress toward completing required courses in the common curriculum, (2) have a GPA ≥ 2.0, and (3) have satisfied the major's course and grade requirements as specified below:

(Majors may impose alternative affiliation requirements for students applying for affiliation later than the first semester of the sophomore year.)

Major	*Courses and Minimum Grade Requirements*
Biological Engineering	At most one grade below C– in math and science courses and CS 100 or its equivalent.
Chemical Engineering	At most one grade below C– in chemistry, math, physics, and chemical engineering courses. GPA ≥ 2.2 in math, science, and engineering courses.
Civil Engineering	GPA ≥ 2.0 in all engineering and science courses. At least C– in ENGRD 202 (or ENGRD 251, for students who do not take ENGRD 202 before affiliation).
Computer Science	At least C in all completed CS and math courses. GPA ≥ 2.5 in CS 211, 212, and 280. GPA ≥ 2.5 in MATH 192 and CS 280. Visit the CS undergraduate office web site for alternative affiliation criteria.
Electrical and Computer Engineering	At least C+ in MATH 293, PHYS 213, and one of ECE/ENGRD 210, ECE 220, and ECE/ENGRD 230. GPA ≥ 2.5 in (if completed): MATH 192, 293, 294, PHYS 213, ENGRD 211, 230, ECE/ ENGRD 210, ECE 220.
Engineering Physics	At least B– in all required math and physics courses.
Environmental Engineering	GPA ≥ 2.0 in all engineering and science courses. At least C– in ENGRD 251.
Independent Major	GPA ≥ 2.0.
Information Science Systems, and Technology	At least C in two of MATH 294, CS 211, and OR&IE/ENGRD 270. Courses must be taken for a letter grade. GPA ≥ 2.3 in completed engineering math, engineering distribution, and ISST major courses, which must be taken at Cornell. For a repeated course, the most recent grade will be used.
Materials Science and Engineering	At least C– in required physics, chemistry, and math courses. At least C in ENGRD 261 or ENGRD 262.
Mechanical Engineering	At least C– in ENGRD 202, ENGRD 221*, and all completed required mathematics, science, and computer science courses. GPA ≥ 2.5 in MATH 293, PHYS 213, ENGRD 202, and ENGRD 221 (if ENGRD 221 was taken). For students entering prior to fall 2005, see affiliation requirements at www.mae.cornell.edu.
Operations Research and Engineering	At least C– in ENGRD 270. GPA ≥ 2.0 in math, science, and engineering courses (both overall and in the semester immediately before affiliation). GPA ≥ 2.0 in ENGRD 270 and all required math courses at the 200 level or above that have been taken thus far.
Science of Earth Systems	Good academic standing in the College of Engineering.

Students must be affiliated or conditionally affiliated with a major by the end of their fourth semester or they will be withdrawn from the College of Engineering, unless allowed to participate in a terminal semester.

SPECIAL PROGRAMS

Dual-Degree Program

The dual-degree program, intended for superior students, allows both a bachelor of science and either a bachelor of arts (B.A.) or bachelor of fine arts (B.F.A.) degree to be earned in about five years. Students registered in the College of Engineering, the College of Arts and Sciences, or the College of Architecture, Art, and Planning may apply and, after acceptance of their application, begin the dual-degree program in their second or third year. For information, contact the appropriate coordinators of dual-degree programs at 55 Goldwin Smith Hall (for Arts and Sciences), B-1 West Sibley Hall (for Architecture, Art, and Planning), and Engineering Advising, 167 Olin Hall.

Double Major in Engineering

The double-major option, which makes it possible to develop expertise in two allied engineering majors, generally requires at least one semester beyond the usual four years. Students affiliate with one major following normal procedures and then petition to enter a second major before the end of their junior year. All requirements of both majors must be satisfied. Further information is available from Engineering Advising, 167 Olin Hall, and the individual major offices.

Independent Major

Students whose educational objectives cannot be met by one of the regular majors may affiliate with the independent major. Often, the desired curriculum is in an interdisciplinary area.

This major consists of a primary area (≥ 32 credits), which may be any subject area offered by a school or department of the college, and an educationally related secondary area (≥ 16 credits), which may be in a second engineering subject area or in a logically connected nonengineering area. The combination must form an engineering education in scope and substance and should include engineering design and synthesis as well as engineering sciences. See the discussion of this major in "Undergraduate Engineering Majors."

Engineering Minors

Most of the majors have a corresponding minor, requiring six courses (18 credits), in which the student can pursue a secondary interest. In addition, there are minors in applied mathematics, biomedical engineering, civil infrastructure, engineering management, engineering statistics, game design, industrial systems and information technology, and information science. See "Engineering Minors."

Engineering Communications Program

424 Hollister Hall, 255-8558, www.engineering.cornell.edu/ECP

The Engineering Communications Program (ECP), created in 1987 at the urging of the College of Engineering faculty and employers of Cornell engineers, provides instruction in technical writing, oral presentation, and the use of graphics in both. The ECP is a recipient of the Engineering Dean's Prize in Excellence and Innovation in Teaching.

ECP courses give students experience with the difficult task of explaining technical information to audiences that have various levels of technical expertise. Students improve their writing style, become more comfortable with and effective at oral presentation, use standard forms and formats for presenting technical information, perform library and Internet research on engineering topics, and study real engineering situations in which ethics may have been breached.

Enrollment in ECP courses is typically 20 students per section; like writing seminars elsewhere at Cornell, those taught by the ECP are discussion classes. Students' work receives abundant written comments, and conferences are frequent.

ECP members are available to consult with the faculty teaching writing-intensive technical courses and anyone else interested in including writing in their courses. They oversee the communications component of the Writing-Intensive Co-op and occasionally give talks to alumni and student groups.

Diversity Programs in Engineering

146 Olin Hall, 255-6403

The Diversity Programs in Engineering (DPE) office operates programs at the undergraduate, graduate, and faculty levels to facilitate the outreach, recruitment, retention, and overall success of underrepresented minorities, women, and other underrepresented groups in Engineering. DPE serves as a resource center for academic support, career placement, graduate school preparation, and overall student success.

The office participates in a university-wide pre-freshman summer program for admitted students, coordinates two summer program initiatives for high school students, Curie (www.engineering.cornell.edu/curie) and CATALYST (www.engineering.cornell.edu/catalyst), and also provides specialized instruction, in collaboration with Engineering Advising and Engineering Learning Initiatives, each semester in subjects such as math, computer science, and English composition.

The DPE office sponsors networking events throughout the academic year that allow company representatives from all over the United States to meet students from diverse populations. Summer internships and permanent jobs frequently result from these events.

In addition, the DPE office coordinates various trips, recreational activities, seminars, lectures, and workshops on a wide range of topics that are relevant to academic and extracurricular life in the university setting.

Engineering Learning Initiatives

167 Olin Hall, 255-9622, www.engineering.cornell.edu/learning

The office of Engineering Learning Initiatives offers programs designed to enhance the undergraduate academic experience through peer education, cooperative learning, research opportunities, and leadership development.

Academic Excellence Workshops (AEWs) offered through Engineering Learning Initiatives are taken in conjunction with core engineering courses in math, computer science, and chemistry. The 1-credit AEWs are weekly two-hour cooperative learning sessions. Designed to enhance student understanding, they feature peer-facilitated group work on problems at or above the level of course material.

Undergraduate Research Grants offered through Engineering Learning Initiatives provide opportunities for students to obtain hands-on research experience with a faculty mentor. Students and faculty may apply for funding to cover student stipend and expense costs for the fall, spring, and summer terms.

Tutors-on-Call, through Engineering Learning Initiatives, offers one-on-one peer tutoring free of charge for engineering students in many first- and second-year core courses, including math, chemistry, physics, computer science, and distribution courses.

LeaderShape, offered through Engineering Learning Initiatives, provides opportunities for our students to engage in the dynamic process of personal discovery and leadership development at a week-long retreat held in May of each year.

Engineering Cooperative Education and Career Services

201 Carpenter Hall, 255-5006, www.engineering.cornell.edu/careerservices

This office assists engineering students (freshmen through Ph.D.) on issues related to career development and the job search through individual advising and group seminars. It also administers the Engineering Cooperative Education Program. Each year, more than 200 national employers visit the office to recruit technical interns and graduates; additional job opportunities are posted electronically through CornellTrak. Both undergraduate and graduate students can use these resources to pursue permanent, summer, or co-op employment; however, students seeking co-op opportunities must meet specific requirements.

The Engineering Cooperative Education Program (Co-op) provides an opportunity for students to gain practical experience in engineering-related organizations before they graduate. By supplementing course work with carefully monitored, paid positions, Co-op students can explore their own interests and acquire a better understanding of engineering as a profession—and still graduate in four years.

To be eligible, a student must have been enrolled in the College of Engineering an equivalent of five semesters before starting the first work term. (Exceptions may be made for transfer students and others pursuing an accelerated curriculum.) Students majoring in computer science or biological engineering, but not registered in the College of Engineering, are also eligible. In most cases, a GPA ≥ 2.7 is required. Applicants interview with participating employers in February of the sophomore year. Those who receive offers and join the program usually complete their fifth-semester course work on campus during the summer after sophomore year and begin the first Co-op work term the following fall. They complete the sixth semester back on campus with their classmates, and then return to their Co-op employer (but not necessarily to the same department or location) the following summer to complete a second work term. Students then spend the senior year back on campus, graduating on schedule with their class. Students who have flexible course curriculums may prefer to complete one 28-week spring/summer or summer/fall Co-op work term during the junior year.

International Programs

An international perspective, sensitivity to other cultures, and the ability to read and speak a second language are increasingly important for today's engineers. The College of Engineering encourages students to study or work abroad during their undergraduate years. Currently, the college has study abroad agreements with École Centrale Paris, France; Cantabria, Spain; and the Hong Kong University of Science and Technology and is also working with IIT Kanpur, India, and the National University of Singapore. The college is working to facilitate study abroad in Dresden, Germany; and Guadalajara, Mexico. Students who plan to study abroad apply through Cornell Abroad; see the Cornell Abroad program description in the introductory section of *Courses of Study*. Visit www.engineering.cornell.edu/studyabroad and Engineering Advising, 167 Olin Hall, for the latest information. In addition, the college is working on an international Co-op work experience. For information, visit the Engineering Cooperative Education and Career Services Office, 201 Carpenter Hall.

Cooperative Program with the Johnson Graduate School of Management

Undergraduates may be interested in a cooperative program at Cornell that leads to both master of engineering and master of business administration (M.B.A.) degrees. See "Master of Engineering Degrees" for details.

Lester Knight Scholarship Program

The Lester Knight Scholarship Program is designed to assist and encourage Cornell Engineering students and alumni interested in combining their engineering education with a business degree. See "Master of Engineering Degrees" for details.

ACADEMIC PROCEDURES AND POLICIES

Advanced Placement Credit

The College of Engineering awards a significant amount of advanced placement (AP) credit to entering first-year students who demonstrate proficiency in the subject areas of introductory courses. Students can earn AP credit by receiving qualifying scores on any of the following:

1. Advanced placement examinations given and scored by the College Entrance Examination Board (CEEB);
2. General Certificate of Education (GCE) Advanced ("A") Level Examinations;
3. International Baccalaureate (IB) Higher Level Examinations; or
4. Cornell's departmental placement examinations, given during orientation week before the beginning of fall-semester classes.

Advanced placement credit is intended to permit students to develop more challenging and stimulating programs of study. Students who receive AP credit for an introductory course may use it in three different ways. They may:

1. enroll in a more advanced course in the same subject right away.
2. substitute an elective course from a different area.
3. enroll in fewer courses, using the AP credit to fulfill basic requirements.

Acceptable Subjects and Scores for CEEB or Cornell Departmental AP Exams

The most common subjects for which AP credit is awarded in the College of Engineering, and the scores needed on qualifying tests, are listed below. AP credit is awarded only for courses that meet engineering curriculum requirements.

Mathematics: MATH 191, 192 are required.

First-semester math (MATH 191). AP credit may be earned by:

- a score of 4 or 5 on the CEEB BC exam, or
- a passing score on the Cornell departmental exam for first-semester math.

First-year math (through MATH 192). AP credit may be earned by:

- a passing score on the Cornell departmental exam for first-year math.

Physics: PHYS 112 and 213 are required.

PHYS 112. AP credit may be earned by:

- a score of 4 or 5 on the mechanics portion of the CEEB C exam, or
- a score of 5 on the CEEB B exam with successful completion of a high school–level calculus course, *or*
- a passing score on the Cornell departmental exam for PHYS 112.

Note: MATH 293 is a prerequisite for PHYS 214.

PHYS 213. AP credit may be earned by a score of 5 on the Electricity and Magnetism portion of the AP C exam.

PHYS 116, 217, and 218 (honors sequence). This sequence is designed for students with strong experience in physics and calculus, e.g., a 5 on one or both Physics C AP tests and the equivalent of at least one semester of university calculus. Students interested in PHYS 217 or 218 are strongly advised to start with PHYS 116. Even for a student with a 5 on both Physics C AP tests, 116 will not be boring. Students may not simultaneously receive credit for PHYS 116 and AP credit for PHYS 112, or credit for PHYS 217 and AP credit for PHYS 213. For advice or more information, contact the departmental representative at 255-6016.

Chemistry: CHEM 209 is required.

CHEM 209. AP credits may be earned by:

- a score of 5 on the CEEB AP exam, or
- a passing score on the Cornell departmental exam for chemistry.

Note: Students who obtain AP credit for CHEM 209 and who are considering a major in chemical engineering or materials science and engineering should consider enrolling in CHEM 215. Those who are offered AP credit for CHEM 209 and then elect to take CHEM 215 will also receive academic credit for CHEM 209. Students may want to discuss this option with their faculty advisor.

Computing: CS 100J or CS 100M, together with CS 101M or CS 101J, are required. AP credit may be earned for CS 100J by:

- a score of 5 on the CEEB A or a score of 4 or 5 on the AB exam, or
- a passing score on the Cornell departmental exam for CS 100J.

Biology: Biology is not required as part of the core curriculum, although it is a popular elective, especially for students who intend to pursue health-related careers. AP credit may be earned as follows:

- 8 credits will be offered to students who receive a 5 on the CEEB AP exam;
- 4 credits will be offered to students who receive a 4 on the CEEB AP.

Those who want to study more biology should contact the Office of Undergraduate Biology, 200 Stimson Hall, to discuss proper placement.

First-year writing seminar: Two first-year writing seminars are required.

- AP credit for one first-year writing seminar may be earned by a score of 5 on either of the CEEB AP English exams.

Students who earn a score of 4 on the AP English Literature and Composition exam or the AP English Language and Composition exam will be offered 3 credits, which may be applied toward the Literature and Arts (LA) category of the Liberal Studies distribution requirement.

Liberal studies distribution: Six courses beyond two first-year writing seminars are required. Students may earn AP credit toward the liberal studies distribution by taking College Entrance Examination Board (CEEB) AP tests. AP credit earned in the liberal studies distribution cannot be used to fulfill the "upper-level" liberal studies requirements.

Languages: Students may earn AP credit for competence in a foreign language by taking the College Entrance Examination Board (CEEB) AP test or by taking the Cornell Advanced Standing Examination (CASE). Those who score 4 or 5 on the CEEB AP test in French, German, Italian, and Spanish are entitled to 3 credits. To qualify for the CASE exam (in any language), the student must score at least 65 on a college placement test (taken either in high school or at Cornell during Orientation Week). A passing score on the CASE entitles the student to 3 credits. Language credit, earned via AP or CASE, may be used to satisfy part of the foreign language category of the liberal studies distribution or may meet an approved elective requirement, contingent on discussions with the faculty advisor.

Advanced Placement and Credit for International Credentials

Students who have successfully completed either a General Certificate of Education (GCE) Advanced ("A") Level Examination or an International Baccalaureate (IB) Higher Level Examination may be eligible for advanced placement credit in the College of Engineering as follows:

General Certificate of Education Advanced Level Examination (GCE "A")

Hong Kong Advanced Level examinations and the joint examination for the Higher School Certificate and Advanced Level Certificate of Education in Malaysia and Singapore—principal passes only—are considered equivalent in standard to GCE "A" Levels.

Subject	*Marks*	*Credit*
Biology	A or B	8 credits
Chemistry	A	8 credits (CHEM 209 and 208)
	B	4 credits (CHEM 209)
Mathematics	A, B, or C	4 credits (MATH 191)
Physics	A or B	4 credits for PHYS 112; 4 additional credits for PHYS 213 are granted to a combination of grades of A or B and a minimum of 4 Advanced Placement (or advanced standing) credits in mathematics.

International Baccalaureate (IB) Higher Level Examination

Subject	*Marks*	*Credit*
Biology	7	8 credits
	6	6 credits
Chemistry	6 or 7	4 credits (CHEM 209)
Computer Science	6 or 7	4 credits (CS 100)
Physics	6 or 7	4 credits (PHYS 112)

Mathematics: No credit is given for the IB exam; students are encouraged to take the Engineering Mathematics Advanced Standing exam during orientation.

Note: Advanced placement credit based on GCE or IB results may also be awarded for courses that satisfy the liberal studies requirement in the College of Engineering. In such cases, the College of Engineering follows the AP guidelines found earlier in this publication under "General Information."

General Policies for Advanced Placement

The general policies in the College of Engineering governing awards of AP credit are as follows:

1. AP credit will not be offered in any subject area without a documented examination.
2. All AP examinations are normally taken and scored before fall-semester classes begin. Students who take CEEB AP tests in high school should have an official report of their scores sent directly to Cornell as soon as possible. Students who have completed either GCE "A" Level or IB Higher Level Examinations must present the original or a certified copy of their examination certificate to Engineering Advising, 167 Olin Hall. Those who wish to take departmental examinations should do so during Orientation Week; permission to take these tests after the start of fall-semester classes must be requested in a written petition to the college's Committee on Academic Standards, Petitions, and Credit (ASPAC).

A more detailed description of the college's policies concerning advanced placement credit and its use in developing undergraduate programs may be found in the pamphlet *Advanced Placement and Transfer Credit for First-Year Engineering Students,* which may be obtained from Engineering Advising, 167 Olin Hall.

General Policies for Transfer Credit

Undergraduate students who have completed courses at recognized and accredited colleges may, under certain conditions, have credits for such courses transferred to Cornell. Such courses must represent academic work in excess of that required for the secondary school diploma and must be documented as such in writing by the secondary institution. Courses deemed acceptable for transfer credit must be equivalent in scope and rigor to courses at Cornell. Transfer credit will not be awarded for courses taken during a semester in which the student is enrolled at Cornell.

- To apply for transfer credit, submit a transfer credit form (one form for each request), accompanied by a course description. (Forms are available from Engineering Advising or the Registrar's office and should be submitted before enrollment in the course to be transferred.) An official transcript from the offering institution (bearing the institutional seal and Registrar's signature) must be sent to the Engineering Registrar's office before official transfer credit will be awarded.
- Applications for transfer credit to satisfy requirements in math, science, engineering courses, or first-year writing seminars require approval from the department offering an equivalent course at Cornell. The department may require course materials, textbooks used, etc., in addition to the course description before approving the course.
- Departmental approval is not required for transfer credit that satisfies liberal studies distribution requirements. The course will be reviewed for approval by a representative of the Committee on Academic Standards, Petitions, and Credit (ASPAC) in Engineering Advising.
- Cornell does not award credit for courses in which a student has earned a grade less than C; schools and departments may stipulate a higher minimum grade.
- College courses completed under the auspices of cooperative college and high school programs will be considered for advanced placement credit only if students demonstrate academic proficiency by taking the appropriate AP or Cornell departmental placement examination (CASE), as described in the "Advanced Credit" section.
- Following matriculation, students may apply up to 18 credits of transfer and/or Cornell extramural credit toward B.S. degree requirements.
- At most 72 total transfer credits (taken both before and after matriculation) may be used to meet graduation requirements.
- Summer session courses taken at Cornell are not considered transfer credit.

A more detailed description of the college's regulations governing transfer credit may be found in the pamphlet *Advanced Placement and Transfer Credit for First-Year Engineering Students* as well as the *Engineering Undergraduate Handbook*, both available from Engineering Advising, 167 Olin Hall.

Transfer Credit for Transfer Students

Transfer students may transfer up to 36 credits for each year spent in full-time study at another institution, provided that the courses are acceptable for meeting graduation requirements. Transfer credit awards are determined by the majors/departments. Students must complete the transfer credit award process by the end of their first semester at Cornell, or their registration will be blocked for the next semester until the process is completed.

Academic Standing

Full-time students are expected to remain in good academic standing. The criteria for good standing change somewhat as a student progresses through the four years of the engineering curriculum. At all times, the student must be making adequate progress toward a degree, but what this means depends on the major.

Engineering students not yet affiliated with a major must meet the following standards at the end of each semester to be considered in good academic standing. Failure to meet these standards will result in a review by the Committee on Academic Standards, Petitions, and Credit (ASPAC), and the actions of warning, stern warning, required leave of absence, or withdrawal from the College of Engineering may be taken.

1. At least 12 credits passed, including *at least* two courses from math, science, and/or engineering (phys. ed. courses and courses below the 100 level do not count)
2. At least C– in the math course
3. Semester GPA ≥ 2.0
4. No F, U, or INC grades

Academic Progress

The total number of credits required for graduation range from 124 to 134, depending on the major. Therefore, an average semester credit load ranges from 15 to 17 credits.

Because math is pivotal to the study and practice of engineering, students must earn at least C– in their four required math courses. If at least C– is not attained, the course must be repeated immediately. Failure to achieve at least C– the second time will generally result in withdrawal from the College of Engineering. Physics and advanced math courses often have math prerequisites, and having to repeat the prerequisite course may delay progress in the physics and math curricula. Students are expected to continue the core engineering math courses each semester until completed.

Dean's List

Dean's List citations are presented each semester to engineering students who have exemplary academic records. The dean of the college determines the criteria for this honor. For 2007–2008, the requirement is a semester GPA ≥ 3.4 (without rounding); no failing, unsatisfactory, missing, or incomplete grades (even in physical education); and at least 12 letter-grade credits (not S-U). Students may earn Dean's List status retroactively if they meet these criteria after making up incomplete grades. Students who earn Dean's List status receive certificates from the engineering registrar's office, and the honor is noted on the transcript.

Graduating with Distinction and Honors

Graduating with Distinction

Meritorious students graduating with a B.S. degree from the College of Engineering may also be designated *cum laude, magna cum laude,* or *summa cum laude.*

- Cum laude will be awarded to engineering students with a GPA ≥ 3.5. Cum laude will also be awarded to engineering students who received a semester GPA ≥ 3.5 in each of the last four semesters at Cornell; in each of these semesters, at least 12 letter-graded credits must be taken with no failing, unsatisfactory, missing, or incomplete grades. If the student is an engineering co-op student, then the engineering co-op summer term will count as one of the last four. Students who were approved for prorated tuition in their final semester will be awarded cum laude if they received a semester GPA ≥ 3.5 in their last semester and meet the conditions above in the prior four semesters.
- Magna cum laude will be awarded to engineering students with a GPA ≥ 3.75 (based on all credits taken at Cornell).
- Summa cum laude will be awarded to engineering students with a GPA ≥ 4.0 (based on all credits taken at Cornell).

Note: All GPA calculations are minimums and are not rounded.

Major Honors Program

To be eligible to enter a major honors program, a student must be on track to graduate with distinction. A student must be in the program for at least two semesters before graduation. If the student's major has an approved honors program and the requirements for (1) distinction, (2) Bachelor of Science degree, and (3) major honors program are fulfilled, the faculty of the major may recommend that the student graduate with the additional diploma and transcript notation of "With Honors."

S-U Grades

Many courses may be taken either for a letter grade or for an S-U (satisfactory or unsatisfactory) grade designation. Under the S-U option, students earning the letter grade equivalent of at least C– in a course will receive a grade of S; those earning less than C– receive U. A course in which a U grade is received does not count toward graduation requirements.

Engineering students may choose to receive an S-U grade option under the following conditions:

- The course in question must be offered with an S-U option.
- The student must previously have completed at least one full semester of study at Cornell.
- The proposed S-U course must count as either a liberal studies distribution or an advisor-approved elective in the engineering curriculum.
- Students may enroll S-U in only one course each semester in which the choice between letter grade and S-U is an option. (Additional courses offered "S-U grades only" may be taken in the same semester as the elected S-U course.)

The choice of grading option for any course is made initially during the pre-enrollment period and may be changed until the end of the third week of classes. After this deadline, the grading option may not be changed, nor will a student be permitted to add a course in which they were previously enrolled (in the current semester) under a different grade option. (Grading options may be changed online for most courses. A properly completed add/drop form must be used to change a grade option for a permission-only course.)

Residence Requirements

Candidates for an undergraduate degree in engineering must spend at least four semesters or an equivalent period of instruction as full-time students at Cornell, including at least three semesters affiliated with an engineering major.

Students on a voluntary leave of absence may register for courses extramurally only with the approval of their major (or the college, for unaffiliated students). No more than 18 credits earned through extramural study or acquired as transfer credit (or a combination thereof) after matriculation may be used to satisfy the requirements for the B.S. degree in engineering. Students may not complete their last semester extramurally.

Degree candidates may spend periods of time studying away from the Cornell campus with appropriate authorization. Information on programs sponsored by other universities and on procedures for direct enrollment in foreign universities is available at the Cornell Abroad office, 474 Uris Hall. Programs should be planned in consultation with the staff of Engineering Advising, who can provide information on credit-evaluation policies and assist in the petitioning process.

Transferring within Cornell

It is not uncommon for students to change their academic or career goals after matriculation in one college and decide that their needs would be better met in another college at Cornell. While transfer between colleges is not guaranteed, efforts are made to assist students in this situation.

The Internal Transfer Division office is responsible for assisting students with the transfer process. Students who wish to transfer out of the College of Engineering to another college at Cornell should consult initially with Engineering Advising.

Students who wish to transfer into the College of Engineering can apply at Engineering Advising, 167 Olin Hall. It is preferred that students apply in the semester in which they are completing affiliation criteria for the desired major. Transfer students who would enter the college must be accepted by a major as part of the admission process.

Students who wish to transfer into engineering should take courses in math, chemistry, computer science, physics, and engineering that conform to the requirements of the Common Curriculum. Students should discuss their eligibility with an advisor in Engineering Advising, 167 Olin Hall.

Leave of Absence

A leave of absence may be voluntary, medical, or required. A description of each follows:

Voluntary leave: Students sometimes find it necessary to suspend their studies. To do this, they must petition for a leave of absence for a specified period of time and receive written approval.

Affiliated students request leave through their majors. Unaffiliated students request leave through Engineering Advising; the first step is an interview to establish conditions for the leave and subsequent return. Those who take a leave before affiliating with a major and while not in good standing may be given a "conditional leave." This requires them to meet specific conditions, established at the time the leave is granted, before they will be reinstated.

A leave of absence generally is not granted for more than two years. A leave of absence granted during a semester goes into effect on the day it is requested. If a leave is requested after the 12th week of a semester, the courses in which the student was registered at the time of the request are treated as having been dropped (i.e., a "W" will appear on the transcript for each course). Students who owe money to the university are ineligible for a leave of absence. Courses taken during a leave to satisfy Cornell degree requirements must be approved *in advance* through a formal transfer petition. (See previous section, "Transfer Credit," for details.)

Students who intend to take a leave of absence should check with the Office of Financial Aid and Student Employment to discuss financial implications; this is especially true for those who have educational loans. Medical insurance eligibility may also be affected.

To return after a leave of absence, the conditions established when the leave was granted must be satisfied, and the college must be notified in writing at least six weeks before the beginning of the semester in which the student plans to return.

Medical leave: Medical leaves are granted by the college only upon recommendation by a physician or therapist from Gannett Health Center. Such leaves are granted for at least six months and up to two years with the understanding that the student may return at the beginning of any semester after the medical condition in question has been corrected. Students must satisfy the Gannett Health Center that the condition has been corrected before they may return. The student's academic standing will also be subject to review both at the time the leave is granted and upon the student's return.

Required leave: A required leave of absence is imposed in cases in which the academic progress of a student is so poor that continuing into the next semester does not appear prudent. An example of this might be failure in key engineering courses in a semester. Unless the student is ahead in the curriculum, returning later to repeat the semester makes better academic sense than continuing without the necessary background. In many cases, the leave is dictated by courses that are offered only in the fall or spring semester. Leaves are given when the probability of success is increased substantially by deferring the student's return by one semester (or, in unusual circumstances, one year).

Rejoining the College

Students wishing to rejoin the college who have not yet affiliated with a major should request permission to rejoin in a letter to Engineering Advising; affiliated students should contact their major office. This must be done at least six weeks before the beginning of the semester in which the student wishes to return. The letter should describe the student's activities while away from Cornell, detail any academic work completed during this time, and specify the courses the student intends to take upon return.

Withdrawal from the College

A withdrawal from the College of Engineering may be voluntary or required. Following is a description of each:

Voluntary withdrawal: Students who voluntarily withdraw from the college sever all connection with the college. Unaffiliated students who wish to withdraw should do so through Engineering Advising. Affiliated students should contact their major office. If a withdrawal is requested during the semester, courses in which the student is enrolled must be dropped in accordance with applicable regulations.

A student who fails to register in the first three weeks of the semester, without benefit of a leave of absence or permission for study in absentia, will be deemed to have withdrawn.

Students who withdraw from the College of Engineering are eligible to apply for admission to one of the other six colleges at Cornell. The intrauniversity transfer process should be followed.

A student who has withdrawn and subsequently wishes to return must make a formal application for readmission. This is rarely granted. It is subject to a review of the student's academic background and depends on available space in the college and in the student's major.

Required withdrawal: Students are required to withdraw from the college only when their overall record indicates that they are either incapable of completing the program or not sufficiently motivated to do so. This action withdraws them only from the College of Engineering and does not, in and of itself, adversely affect their ability to transfer and complete a degree in one of the other colleges in the university.

ENGINEERING MAJORS

This section describes the majors in the College of Engineering: the programs in which an undergraduate can study to obtain a B.S. degree.

A basic requirement of any major is a GPA ≥ 2.0. Most majors have a higher GPA requirement and may have other requirements.

Honors Program within Majors

Many of the engineering majors supplement the major with an honors program.

Eligibility

The B.S. degree with honors is granted to engineering students who, *in addition* to having completed the requirements for a B.S. degree in a major, satisfactorily complete the honors program in the major and are recommended for the degree by the honors committee of that major. To enter an honors program, the student must be on track to graduate with distinction, and a student who does not stay on track to graduate with distinction is dropped from the honors program.

Courses taken to satisfy the honors requirement may not be used to satisfy B.S. degree requirements. At least 9 extra credit hours are required, and a student must be in the program for at least two semesters before graduation.

No research, independent study, or teaching for which the student is paid may be counted toward the honors program.

Procedures

An applicant to the honors program in a major must have an honors advisor: a faculty member from that major who will supervise the honors program and direct the research or project. The honors advisor need not be the student's advisor in the major.

The application for the honors program should be a letter from the student that describes the proposed honors program in detail and includes the explicit approval of the honors advisor.

Students must complete a written application no later than the beginning of the first semester of their senior year, but they are encouraged to make arrangements with the honors advisor during the second semester of their junior year. Each major may place further constraints on timing.

Major-Specific Information

Each major defines the content of the honors program and may also place other requirements on the program, in terms of timing, content, and procedures. Information is given within the description of the individual majors.

BIOLOGICAL ENGINEERING

Offered by the Department of Biological and Environmental Engineering

Contact: 207 Riley-Robb Hall, 255-2173, www.bee.cornell.edu

This major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Biological and environmental engineering (BEE) programs address three great challenges facing humanity today: ensuring an adequate and safe food supply in an era of expanding world population; protecting and remediating the world's natural resources, including water, soil, air, biodiversity, and energy; and developing engineering systems that monitor, replace, or intervene in the mechanisms of living organisms. The biological engineering (BE) major has a unique focus on biological systems, including the environment, which is realized through a combination of fundamental engineering sciences, biology, engineering applications and design courses, and liberal studies.

Students interested in the BE major should have a strong aptitude for the sciences and math and an interest in the complex social issues that surround technology.

Students take courses in math, engineering, statistics, programming, physics, chemistry, basic and advanced biology, fundamental engineering sciences (mechanics, thermodynamics, fluid mechanics, and transport processes), and engineering design. Students select upper-level engineering courses in subjects that include bioprocessing, soil and water management, biotechnology applications, bioinstrumentation, engineering aspects of animal physiology, environmental systems analysis, sustainable energy, and waste management and disposal. Students may further strengthen their programs by completing a minor or a second engineering major. Students planning for medical school also take additional lab-based courses in chemistry and biology. Throughout the curriculum, emphasis is placed on communications and teamwork skills, and all students complete a capstone design project.

Career opportunities cover the spectrum of self-employment, private industry, public agencies, educational institutions, and graduate and professional programs in engineering and science, as well as professional fields like medicine, business, and law. In recent years, graduates have pursued careers in consulting, biotechnology, the pharmaceutical industry, biomedical engineering, management, and international development.

The living world is all around us and within us. The biological revolution continues, and it has given rise to a growing demand for engineers who have studied biology, who have strong math and science skills, who can communicate effectively, and who are sensitive to the needs of people and interested in the challenges facing society. The Biological Engineering major is designed to educate the next generation of engineers to meet these challenges.

The academic requirements* for students majoring in Biological Engineering are outlined below.

Basic Subjects	*Credits*
MATH 191**, 192, 293, 294	
Calculus for Engineers and Engineering Mathematics	16
PHYS 112, 213	8
CHEM 209* General Chemistry	4
CHEM 257 or 357* Organic Chemistry	3
BEE 151 Introduction to Computer Programming or CS 100M, and CS 101J	5
Biological Sciences*	15
Introductory (BIO G 101–104 recommended)	8
Biological science course(s) at or above 200 level	7
Biochemistry and Microbiology recommended	
Major-required courses	46
BEE 200 The BEE Experience or ENGRG 150 (counted as an approved elective)	1
ENGRD 202 Mechanics of Solids	4
BEE 260 Biological Engineering Analysis or 251 Environmental Engineering Analysis	3
BEE 350 Biological and Environmental Transport Processes	3
BEE 222 or ENGRD 221 Thermodynamics	3
ENGRD 270 or CEE 304 Engineering Statistics and Probability	3–4
BEE 331 or CEE 331 Fluid Mechanics	4
Major-approved Engineering Electives (must include minimum of 9 credits of BEE courses, one course must be a BEE Capstone course and one course must be an approved lab experience course:)***	
Concentration courses (three courses, minimum of 9 credits, chosen from one of the following BE concentrations): Biomedical Engineering, Bioprocess Engineering, or Bio-Environmental Engineering.***	
Engineering electives (Engineering courses at 200 level or above to bring the total of required plus engineering electives to 46 credits)	
Liberal studies (two first-year writing seminars and six liberal studies electives)	24
Advisor-approved electives	6
Total (minimum)	127

*Basic accredited curriculum. Engineering minors may be accommodated by course selection in the major plus additional electives as outlined in the engineering undergraduate handbook. Information on preprofessional study for medicine, dentistry, and veterinary medicine is available at www.career.cornell.edu.

** All students must have a competency in calculus equivalent to MATH 111 before they attempt MATH 191.

*** See department for a list of approved courses.

Students must satisfy the College of Engineering Technical Writing requirement by including one of the approved courses in their program of study.

Biological Engineering Honors Program

The B.S. degree with honors is granted to biological engineering majors who graduate with distinction from the College of Engineering and satisfy the Honors requirements given at the beginning of the section "Engineering Majors."

The Honors program requires completion of 9 credits beyond the B.S. degree requirements drawn from the following, with at least 6 credits in the first category:

1. A significant research experience or honors project under the supervision of a BEE faculty member using BEE 495 BE Honors Research completed in their senior year. A written senior honors thesis must be submitted as part of this component.
2. A significant teaching experience under the direct supervision of a faculty member or as part of a regularly recognized course in the department under BEE 498 Undergraduate Teaching.
3. Advanced or graduate courses. These additional courses must be technical in nature, i.e., in engineering, math, biology, chemistry, and physics at the 400+ and graduate level.

CHEMICAL ENGINEERING

Offered by the School of Chemical and Biomolecular Engineering

Contact: 120 Olin Hall, 255-8656, www.cheme.cornell.edu

This major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

The undergraduate major in chemical engineering comprises a coordinated sequence of courses beginning in the sophomore year and extending through the fourth year. Students who plan to enter the major take CHEM 208 during the freshman year. The program for the last three years is as follows:

Semester 3	*Credits*
MATH 293 Engineering Mathematics	4
PHYS 213 Physics II, Heat/Electromagnetism	4
CHEM 389 Physical Chemistry I (engineering distribution)	4
ENGRD 219 Mass and Energy Balances (engineering distribution)	3
CS 101 Transition to OO or MATLAB Programming	1
Liberal Studies Distribution	3
Semester 4	
MATH 294 Engineering Mathematics	4
CHEME 323 Fluid Mechanics	3
CHEM 390 Honors Physical Chemistry II (major)	
CHEM 290 Introductory Physical Chemistry Laboratory (major)	6
Biology elective*	3
Liberal Studies Distribution	3
Semester 5	
CHEM 357 Organic Chemistry for the Life Sciences	3
CHEM 251 Introduction to Experimental Organic Chemistry	2
CHEME 313 Chemical Engineering Thermodynamics	3
CHEME 324 Heat and Mass Transfer	3
Liberal Studies Distribution	3
Semester 6	
Advanced science elective**	3
CHEME 301 Nonresident Lectures	1
CHEME 332 Analysis of Separation Processes	3
CHEME 372 Introduction to Process Dynamics and Control	2
CHEME 390 Reaction Kinetics and Reactor Design	3
Liberal Studies Distribution	3
Semester 7	
CHEME 432 Chemical Engineering	
Laboratory	4
Electives***	9
Liberal Studies Distribution	3
Semester 8	
CHEME 462 Chemical Process Design	4
Liberal Studies Distribution	3
Electives***	3
Approved elective	3

*Every student must complete one of the five following options for the biology elective: (1) CHEME 288 Biomolecular Engineering: Fundamentals and Applications. (2) advanced placement: a score of 5 on the CEEB AP exam or a score of 7 on the IB Higher Level exam. (3) 4 credits of a pre-med biology sequence: BIO G 101 Biological Sciences, Lec (fall, 2 credits) and BIO G 103 Biological Sciences, Lab (fall, 2 credits), BIO G 102 Biological Sciences, Lec (spring, 2 credits) and BIO G 104 Biological Sciences, Lab (spring, 2 credits), BIO G 105 Introductory Biology (fall, 4 credits), BIO G 106 Introductory Biology (spring, 4 credits), BIO G 107 General Biology (summer, first half of eight-week session, 4 credits) or BIO G 108 General Biology (summer, second half of eight-week session, 4 credits). (4) 3 credits of microbiology: BIOMI 290 General Microbiology (fall, spring, or summer six-week session, 3 credits). (5) 4 credits of biochemistry: BIOBM 330 Principles of Biochemistry, Individual Instruction (fall or spring, 4 credits) or BIOBM 333 Principles of Biochemistry: Proteins, Metabolism, and Molecular Biology (summer six-week session, 4 credits). (6) 5 credits of biochemistry: BIOBM 331 Principles of Biochemistry: Proteins and Metabolism (fall, 3 credits) and BIOBM 332 Principles of Biochemistry: Molecular Biology (spring, 2 credits).

**Advanced science electives include BIOMI 290 General Microbiology Lectures; BIOBM 330, 331, 332, and 333 Principles of Biochemistry; BME 301 (CHEME 401) Molecular Principles of Biomedical Engineering; BME 302 (CHEME 402) Cellular Principles of Biomedical Engineering; CEE 451 Microbiology for Environmental Engineering; CEE 654 Aquatic Chemistry; CHEME 470 Process Control Strategies; CHEME 480 Chemical Processing of Electronic Materials; CHEME 481 (BME 481) Biomedical Engineering; CHEME 484 Microchemical and Microfluidic Systems; CHEME 521 Introduction to Biomedical Engineering Module; CHEME 522 Introduction to Electronic Materials Processing Module; CHEME 523 Introduction to Polymer Processing; CHEME 524 Turbo Machinery Applications; CHEME 525 Chemical Engineering Tools and Equipment; CHEME 526 Hydrocarbon Resource Exploration and Development; CHEME 527 Introduction to Petroleum Refining; CHEME 528 Renewable Resources from Agriculture; CHEME 543 Bioprocess Engineering; CHEME 564 Design of Chemical Reactors; CHEME 631 (BME 631) Engineering Principles for Drug Delivery; CHEME 640 Polymeric Materials; CHEME 644 Aerosols and Colloids; CHEME 661 Air Pollution Control; FD SC 417 Food Chemistry I; M&AE 423 Intermediate Fluid Dynamics; MS&E 206 Atomic and Molecular Structure of Matter; MS&E 305 Electronic, Magnetic, and Dielectric Properties of Materials; MS&E 521 Properties of Solid Polymers; MS&E 524 Materials Chemistry of Synthetic Polymeric Materials; MS&E 531 Introduction to Ceramics; MS&E 541 (ECE 536) Nanofabrication for M.Eng.; T&AM 310 Advanced Engineering Analysis I; T&AM 311 Advanced Engineering Analysis II; any A&EP course numbered 333 or above; any CHEM course numbered 301 or above; any PHYS course numbered 300 or above.

***The electives in semesters 7 and 8 comprise 6 credits of major-approved electives and 6 credits of advanced CHEME electives. Advanced CHEME electives include any CHEME course at the 400+ level except CHEME 490, 499, 520–529, and 572.

CIVIL ENGINEERING

Offered by the School of Civil and Environmental Engineering

Contact: 221 Hollister Hall, 255-3412, www.cee.cornell.edu

This major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

While it is not necessary to do so, students may concentrate in environmental engineering, environmental fluid mechanics and hydrology, geotechnical engineering, structural engineering, transportation, or water resource systems.

Admission Requirements

Students planning to affiliate with this major must complete ENGRD 202 Mechanics of Solids (or, for students following the Environmental Concentration, ENGRD 251) with at least a C–. It is strongly recommended that ENGRD 202 be taken as an engineering distribution during the first semester of the sophomore year.

Engineering Distribution Courses

Majors are required to take ENGRD 202 Mechanics of Solids as an engineering distribution course. For the second engineering distribution course, one of the following is recommended:

ENGRD 261 Introduction to Mechanical Properties of Materials for students interested in structural engineering and geotechnical engineering.

ENGRD 221 Thermodynamics for students interested in fluid mechanics and hydraulics/hydrology.

ENGRD 211 Computers and Programming for students interested in transportation.

ENGRD 251 Engineering for a Sustainable Society for students interested in environmental engineering.

Major Program

Students may substitute CHEM 208 or CHEM 257 for PHYS 214. The following nine courses are required in addition to those required for the Common Curriculum. (Students interested in the Environmental Concentration should follow the course requirements for the Environmental Engineering Major and should refer to the CEE Undergraduate Handbook for requirements specific to CE majors. CE majors should take CEE 341.)

Core Courses	*Credits*
ENGRD 203 Dynamics* or CEE 478 Structural Dynamics	3
ENGRD 320 Engineering Computation* (formerly ENGRD 241)	3
CEE 304 Uncertainty Analysis in Engineering†	4
CEE 323 Engineering Economics and Management	3
CEE 331 Fluid Mechanics	4
CEE 341 Introduction to Geotechnical Engineering and Analysis	4
CEE 351 Environmental Quality Engineering**	3
CEE 361 Introduction to Transportation Engineering**	3
CEE 371 Structural Modeling and Behavior	4

Additional requirements include a set of two major-approved electives and three design electives from a list of approved courses that is available in the school office. In addition, students must complete one technical communications course from among the courses designated ENGRC or approved communications courses. If the technical communications course also fulfills another requirement (liberal studies major–approved elective, etc.), then an additional advisor-approved elective must be taken.

*ENGRD 203 and ENGRD 320 can be used to satisfy a major requirement. If a student elects to use one of these courses as a second distribution course, the student must take an additional major-approved elective to fulfill the core course requirements.

†ENGRD 270 may be accepted (by petition) as a substitute for CEE 304 in the major, but only if ENGRD 270 is taken before affiliation, or in some special cases where co-op or study abroad programs necessitate such a substitution.

**Students may substitute CEE 372 or CEE 471 for either CEE 351 or 361, if they also complete either CEE 473 or 474. However, CEE 372 or CEE 471 then counts as a core course only and not as a CEE design course or major-approved elective. Students may also substitute CEE 461 for CEE 351 if they also take two of these three courses: CEE 463, 464, and 465. However, then CEE 461 counts as a core course only and not as a CEE design course or major-approved elective.

Civil Engineering Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the following requirements.

The 9 credits beyond the B.S. degree requirements shall be drawn from the following components (with no fewer than 2 credits in any selected component):

1. A significant research experience or honors project under the direct supervision of a CEE faculty member using CEE 400 Senior Honors Thesis (1–6 credits per semester). A significant written report or senior honors thesis must be submitted as part of this component. Letter grades only.
2. A significant teaching experience under the direct supervision of a faculty member or as part of a regularly recognized course in the College of Engineering, i.e., ENGRG 470 Peer Teaching in Engineering or CEE 401 Undergraduate Teaching in CEE (1–3 credits per semester).
3. Advanced or graduate courses at the 500 level or above.

Procedures

Application to the program shall be a registration form for CEE 400 and a letter from the student describing the specific proposed honors program and including the explicit approval of the major advisor and the honors advisor. The program must be approved by the CEE Curriculum Committee, although the committee may delegate approval authority to the associate director for all but unusual proposals.

COMPUTER SCIENCE

Offered by the Department of Computer Science

Contact: 303 Upson Hall, 255-0982, www.cs.cornell.edu

The Department of Computer Science is affiliated with both the College of Arts and Sciences and the College of Engineering. Students in either college may major in computer science.

Computer science majors take courses in algorithms, data structures, logic, programming languages, scientific computing, systems, and theory. Electives in artificial intelligence, computer graphics, computer vision, databases, multimedia, and networks are also possible. Requirements include:

- MATH 191, 192, and 294
- three courses in introductory computing; either CS 100J, CS 101M, CS 211 or CS 100M, CS 100J, CS 211
- a 1-credit project (CS 212)
- a seven-course computer science core (CS 280, 312, 314, or 316; one of 321, 322, 421, 422, or 428; 381, 414, and 482)
- two 400+ level computer science electives, 3+ credits each, totaling at least 6 credits (CS 490 not allowed)
- a computer science project course (CS 413, 415, 419, 433, 466, 473, 501, 514, or 664)
- a math elective course (e.g., ENGRD 270, MATH 293, MATH 300+, T&AM 310)
- two 300+ level courses (major-approved electives) that are technical in nature and total at least 6 credits
- a three-course specialization in a topic area other than computer science, all numbered 300 level or greater

All the major electives described above must be courses of at least 3 credits, with the exception of the CS project course, which is at least 2 credits.

The program is broad and rigorous, but it is structured in a way that supports in-depth study of outside areas. Intelligent course selection can set the stage for graduate study or employment in any technical area or any professional area such as business, law, or medicine. With the advisor, the computer science major is expected to put together a coherent program of study that supports career objectives and is true to the aims of a liberal education.

Computer Science Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" with a set of coherent courses and research activities that satisfy the following requirements.

1. at least one CS course (at least 3 credit hours) at or above the 500 level with a grade of A– or better (no seminars)
2. at least two 3-credit semesters of CS 490 (independent research), with grades of A– or better each semester

Honors determinations are made during the senior year. Students wanting to be considered for the honors program should notify the undergraduate office in the Department of Computer Science at ugrad@cs.cornell.edu. The subject line for this message should read "HONORS TRACK". Address related questions to the same e-mail address; call or stop by 303 Upson Hall, 255-0982; or visit www.cs.cornell.edu/ugrad for more information on eligibility.

ELECTRICAL AND COMPUTER ENGINEERING

Offered by the School of Electrical and Computer Engineering

Contact: Student Services Office, 223 Phillips Hall, 255-4309, www.ece.cornell.edu

This major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

The Electrical and Computer Engineering major (ECE), leading to a B.S. degree, provides a foundation that reflects the broad scope of this engineering discipline.

Concentrations include computer architecture and organization, digital systems and computer vision; power systems, control, optimization, numerical and state-space methods; communications, computer networks, information theory and coding, signal processing; electronic circuits, VLSI, solid state physics and devices, MEMs, nanotechnology, lasers and optoelectronics; electromagnetics, radiophysics, space sciences, plasmas.

Students planning to affiliate with ECE must take ECE/ENGRD 230 as an engineering distribution course. Prospective majors are encouraged, but not required, to take ENGRD 211 as the other engineering distribution course. The major normally begins in the spring of the sophomore year. Of the courses listed below, only ENGRD/ECE 210, ECE 220, ECE/ENGRD 230, and ECE 315 are taught in both the fall and spring semesters.

Course	*Credits*
Major-required courses	
ECE/ENGRD 210 Introduction to Circuits for Electrical and Computer Engineers	4
ECE 220 Signals and Information	4
ECE/ENGRD 230 Introduction to Digital Logic Design	4
ECE 303 Electromagnetic Fields and Waves	4
ECE/CS 314 Computer Organization	4
ECE 315 Introduction to Microelectronics	4
ECE 320 Networks and Systems	4
Major-approved electives *(29-credit minimum in the following categories)*	
Advanced ECE electives†	(six lecture courses)
Outside ECE electives‡	9 minimum credits
Total minimum major credits	53

ECE 310 should be taken to satisfy the major requirement of probability and statistics requirement. Alternatively, a student may take either ENGRD 270 or T&AM 310.

†These electives must include two 400-level Electrical and Computer Engineering culminating design experience (CDE) courses and at least two additional courses at the 400 level or above. The remaining electives may not include independent project courses, such as ECE 391, 392, 491, or 492, and must be at the 300 level or above in Electrical and Computer Engineering.

Courses that meet the CDE requirement are described in the *Engineering Undergraduate Handbook*. The list is dynamic and changes frequently. An updated list of courses that meet the CDE requirements will be posted each semester on the bulletin board outside 222 Phillips Hall. All courses must have a college-level prerequisite.

‡Must include one course at the 300 level or above (see *Electrical and Computer Engineering Web Handbook* for details).

Undergraduate concentration is achieved through the various Electrical and Computer Engineering elective courses, as well as other courses in related technical fields within engineering, math, the physical sciences, and the analytical biological sciences. The School of Electrical and Computer Engineering offers more than 30 courses that are commonly taken as electives by undergraduates.

Academic Standards

Majors in Electrical and Computer Engineering are expected to meet the following academic standards:

1. GPA $\geq$ 2.3 every semester.
2. At least C– in all courses used to satisfy degree requirements in the major or that serve as a prerequisite for a subsequent Electrical and Computer Engineering course.
3. Satisfactory completion of MATH 294, PHYS 214, and two of ENGRD/ECE 210, ECE 220, and ENGRD/ECE 230 by the end of the sophomore year and adequate progress toward the degree in subsequent semesters.

Electrical and Computer Engineering Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the following requirements:

Students must apply during the first three weeks of the sixth semester. They must achieve a B or better in the three required courses taken for honors designation.

Honors Seminar

Prospective honors students must take an honors seminar in the spring semester of their junior year, for a letter grade and 2 credits. The honors seminar consists of a weekly series of introductory research lectures by ECE faculty members. Each honors seminar enrollee will write two short papers on topics covered in the lecture series. Many ECE faculty members will give a lecture or short series of lectures as part of the honors seminar.

Honors Project

A student in the honors program is required to accumulate at least 3 credit hours from a senior-year honors project with an ECE faculty member, consisting of either design, research, or directed reading at the 400 level. All honors projects emphasize the development of communication skills. Design- and reading-oriented honors projects explicitly require a written submission summarizing and concluding the project.

Additional Course Work

At least 3 credit hours are required of advanced (senior level) ECE course work that has at least a 300-level prerequisite. These credit hours are in addition to any credit hours required as part of the ECE major.

The requirement for at least 9 credits over and above the 130 credits required for a B.S. degree means that an honors degree requires 139 credit hours.

ENGINEERING PHYSICS

Offered by the School of Applied and Engineering Physics

Contact: 212 Clark Hall, 255-5198, www.aep.cornell.edu

The engineering physics (EP) major is designed for students who want to pursue careers of research or development in applied science or advanced technology and engineering. Its distinguishing feature is a focus on the physics and math fundamentals, both experimental and theoretical, that are at the base of modern engineering and research and have a broad applicability in these areas. By choosing areas of concentration within this major, students may combine this physics base with a good background in a conventional area of engineering or applied science.

The industrial demand for EP B.S. graduates is high, and many students go directly to industrial positions where they work in a variety of engineering or developmental areas that either combine, or are in the realm of, various more conventional areas of engineering. Recent examples include bioengineering, computer technology, electronic-circuit and instrumentation design, energy conversion, environmental engineering, geological analysis, laser and optical technology, microwave technology, nuclear technology, software engineering, solid-state-device development, technical management, and financial consulting. A number of EP graduates go on for advanced study in all areas of basic and applied physics as well as in a diverse range of areas in advanced science and engineering. Examples include applied physics, astrophysics, atmospheric sciences, biophysics, cell biology, computer science and engineering, electrical engineering, environmental science, fluid mechanics, geotechnology, laser optics, materials science and engineering, mathematics, mechanical engineering, medical physics, medicine, nuclear engineering, plasma physics, oceanography, and physics. The major can also serve as an excellent preparation for medical school, business school, or specialization in patent law.

The EP major fosters this breadth of opportunity because it both stresses the fundamentals of science and engineering and gives the student direct exposure to the application of these fundamentals. Laboratory experimentation is emphasized, and ample opportunity for innovative design is provided. Examples are ENGRI/A&EP 110 Lasers and Photonics; ENGRI/A&EP 102 Introduction to Nanoscience and Nanoengineering; ENGRD 242/A&EP 252 Physics of Life; ENGRD/A&EP 264 Computer-Instrumentation Design (a recommended sophomore engineering distribution course); A&EP 330 Modern Experimental Optics (a junior/senior course); A&EP 363 Electronic Circuits (a sophomore/junior course); PHYS 410 Advanced Experimental Physics; and A&EP 438

Computational Engineering Physics (a senior computer laboratory).

Students who plan to affiliate with the EP major are advised to arrange their common curriculum with their developing career goals in mind. They are encouraged to take PHYS 112 or 116 during their first semester (if their advanced placement credits permit) and are recommended to satisfy the technical writing requirement with the engineering distribution course ENGRD 264. EP students need to take only one engineering distribution course, since A&EP 333, taken in the junior year, counts as the second one. EP students are advised to take A&EP 363 (taking ECE 210 and 230, 4 credits each, can satisfy A&EP 363. Count ECE 210 as an approved elective and ECE 230 as A&EP 363) in the spring semester of the sophomore year. Students with one semester of advanced placement in math and who have received at least A– in MATH 192 may wish to explore accelerating their math requirements so as to enroll in A&EP 321 and 322 in the sophomore year. For advice on this option, consult with the A&EP associate director.

In addition to the requirements of the Engineering Common Curriculum,* the major requirements are as follows:

Course	*Credits*
A&EP 333 Mechanics of Particles and Solid Bodies	4
A&EP 355 Intermediate Electromagnetism	2
A&EP 356 Intermediate Electrodynamics	4
A&EP 361 Introductory Quantum Mechanics	2
A&EP 362 Intermediate Quantum Mechanics	4
A&EP 363 Electronic Circuits	4
A&EP 423 Statistical Thermodynamics	4
A&EP 434 Continuum Physics	4
PHYS 410 Advanced Experimental Physics	4
A&EP 321 Mathematical Physics I; or	
MATH 421 (applied mathematics)	4
A&EP 322 Mathematical Physics II; or	
MATH 422 (applied mathematics)	4

Six major-approved electives (18–23 credits), of which five must be technical upper-level courses (300 or above).

Total major credits=58 credit hours minimum

*The Engineering Common Curriculum suggests that freshmen take only four courses each semester. This course load is fully consistent with the requirements of the EP major, but freshmen with strong preparation are encouraged to consider taking an additional course during one or both semesters so that they may have additional flexibility in developing a strong, individualized educational program in their later years and for allowing options such as a semester or year abroad or early graduation.

Two of the 4 credits of PHYS 410 required for the B.S. degree in EP can be satisfied by completing A&EP/PHYS 330 or ASTRO 410. The remaining 2 credits of PHYS 410 can then be satisfied by taking PHYS 400 for 2 credits, provided that the experiments completed in PHYS 400 do not overlap with those in A&EP/PHYS 330 or ASTRO 410. (A list of experiments that are not appropriate will be prepared by A&EP faculty and made available in the A&EP office.) If a student chooses this option, A&EP/PHYS 330 or ASTRO 410 may also count as a technical elective, provided the remaining three technical electives are 4 credits each.

Choosing elective courses. The EP major provides the students with a strong opportunity to develop individualized programs of study to meet their particular educational and career goals. These can include the pursuit of a dual major or the development of a broad expertise in a number of advanced technical and scientific areas. With at least seven electives in the sophomore, junior, and senior years, EP majors are encouraged to work closely with their advisor to develop a coherent academic program that is consistent with those goals. For students who look toward an industrial position after graduation, the electives should be chosen to widen their background in a specific area of practical engineering. A different set of electives can be selected as preparation for medical, law, or business school. For students who plan on graduate studies, the electives provide an excellent opportunity to explore upper-level and graduate courses and to prepare for graduate study in any one of a number of fields. Various programs are described in a special brochure available from the School of A&EP, Clark Hall. Students are advised to consult with their EP advisor, a professor active in their area of interest, or with the associate director of the school.

Electives need not be all formal course work: qualified students are encouraged to undertake independent study under the direction of a member of the faculty (A&EP 490). This may include research or design projects in areas in which faculty members are active.

The variety of course offerings and many electives provide flexibility in scheduling. If scheduling conflicts arise, the school may allow substitution of courses nearly equivalent to the listed required courses.

Academic Standing

Students are expected to pass every course in which they are registered, to earn at least C– in specifically required courses, and to attain a semester GPA ≥ 2.3 each semester.

Engineering Physics Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the following requirements.

1. At least 8 credits of major-approved electives at the 400 level or higher with at least A– in each, not counting credits given for item 2.
2. Two semesters of A&EP 490 or an equivalent course, with at least 2 credits the first semester and 4 credits the second. The student will complete an independent research project or senior thesis under the supervision of an engineering or science faculty member. The level of work required for successful completion is to be consistent with the amount of academic credit granted.

Procedures

Before enrolling in A&EP 490 or the equivalent, the honors candidate must submit a brief proposal outlining the topic and scope of the project or thesis and an honors advisor's written concurrence to the associate director for undergraduate studies. This proposal will be reviewed by the A&EP Honors Committee and either approved or returned to the candidate to correct deficiencies. The proposed project or thesis is to consist of a research, development, or design project and must go beyond a literature search. The final steps in completing the honors project are a written and oral report. The written report is to be in the form of a technical paper with, for example, an abstract, introduction, methods section, results section, conclusions section, references, and figures. This report will be evaluated by the faculty supervisor and the chair of the A&EP Honors Committee. Following completion of the written report, an oral report is to be presented to an audience consisting of the faculty supervisor, the chair of the Honors Committee, and at least one other departmental faculty member, along with the other honors candidates. A copy of the final report is to be given to the chair of the A&EP Honors Committee. The final research project course grade will be assigned by the faculty supervisor after consultation with the chair of the Honors Committee. At least A– is required for successful completion of the honors requirement.

ENVIRONMENTAL ENGINEERING

Offered jointly by the Department of Biological and Environmental Engineering and the School of Civil and Environmental Engineering.

Contact: 221 Hollister Hall, 255-3412, www.cee.cornell.edu, or 207 Riley-Robb Hall, 255-2173, www.bee.cornell.edu

Environmental Engineering is the study and practice of analyzing, designing, and managing natural and engineered systems in ways consistent with the maintenance or enhancement of environmental quality and sustainability. It requires the ability to predict multiple interactions and impacts among natural and engineering-system components at various spatial and temporal scales in response to alternative design and management policies. It requires a thorough understanding of the interactions among the natural environment, the constructed environment, and human activities.

The Environmental Engineering major is available in Civil and Environmental Engineering and Biological and Environmental Engineering.

Students matriculating in the College of Engineering (COE) may affiliate with this major in their second year. Students matriculating in the College of Agriculture and Life Sciences (CALS) may enroll in this major in their first semester. Students planning to affiliate with this major will be taking the following courses:

Mathematics-science core requirements

Course	*Credits*
MATH 191, 192, 293, 294	16
PHYS 112, 213	8
CHEM 209 or 257	7
CS 100J, CS 100M, or BEE 151* followed by CS 101M or CS 101J	5

Introduction to engineering^^^ 3

ENGRI 113 Sustainability Design for Appledore Island (recommended), or

BEE 200 The BEE Experience* (required for students matriculating in CALS)

Engineering distribution courses†

ENGRD 251 Engineering for a Sustainable Society (required) 3

ENGRD 202 (required), 241, or 221 are recommended or BIO G 101–103, BIO G 105, BIO G 107 may be used) 3–4

Major-required courses

Major Courses		*Credits*
BIO G 109	Introductory Biology** (students may also use BIO G 101–103 or BIO G 105 or BIO G 107, to satisfy the biology requirement)	3–4
ENGRD 202	Mechanics of Solids**	4
ENGRD 320	Engineering Computation (formerly ENGRD 241)**	3
or		
ENGRD 221	Thermodynamics**	3
CEE 304	Uncertainty Analysis in Engineering***	4
CEE 331	Fluid Mechanics	4
Earth Science (one from the following list):		3–4
CEE 341	Introduction to Geotechnical Engineering and Analysis	
or		
EAS 201	(ENGRD 201) Introduction to the Physics and Chemistry of the Earth**	
or		
EAS 303	Introduction to Biogeochemistry	
or		
CSS 365	Environmental Chemistry: Soil, Air, and Water	
or		
BEE 371	Physical Hydrology for Ecosystems	
CEE 351	Environmental Quality Engineering	3
CEE 451	Microbiology for Environmental Engineering††	3
Laboratory Course (one from the following list):		
CEE 453	Lab Research in Environmental Engineering	3
or		
BEE 427	Water Sampling and Measurement	
or		
BEE 473	Watershed Engineering	
or		
CEE 437	Experimental Methods in Fluid Dynamics	
BEE 475	Environmental Systems Analysis	3–4
Engineering Economics:		3–4
CEE 323	Engineering Economics and Management	
or		
BEE 489	Engineering Entrepreneurship, Management, and Ethics	

Electives

Technical communications course††† (ENGRC 335 or 350; COMM 260, 263, or 352 in liberal studies category; or BEE 493 taken with BEE 473 or BEE 493 taken with BEE 450; or BEE 489) 4–5

Three Environmental design electives chosen from the list of approved courses 9-credit minimum‡

Two major-approved engineering electives to complete total credit requirement‡‡ 6

Two approved electives 6

Total credits (minimum) 126

^^^COE matriculated students must complete one ENGRI 1XX course their first year. CALS matriculated students may complete BEE 151 and BEE 200 to meet the requirement.

*BEE 151 and 200 together (5 credits) satisfy the ENGRI requirement for CALS–matriculated first-year students. Students using BEE 200 and BEE 151 to satisfy the ENGRI requirement must make up the 2-credit difference with engineering course work.

**Students using this course as a second engineering distribution must take an additional major-approved elective. BIO G 109 is not an engineering distribution course.

***ENGRD 270 (f,s,3) may be accepted (by petition) to substitute for CEE 304 if taken prior to affiliation with the Environmental Engineering major or if necessary because of scheduling conflicts caused by co-op or study abroad.

†Students must complete two ENGRD courses.

††Students planning graduate-level study in Environmental Engineering should take BIOMI 290 Introduction to Microbiology in place of CEE 451.

†††If the course fulfilling the technical writing requirement also fulfills another requirement (e.g., liberal studies, major-approved elective), then it may be used to satisfy both requirements.

‡To be chosen from a list of design courses. Students are encouraged to take CEE 452, CEE 454, or BEE 473.

‡‡The list of suggested courses covers the areas of environmental engineering, hydraulics/hydrology, environmental systems engineering, geotechnical engineering, remote sensing, air pollution, and renewable energy systems. The respective lists are available at the departmental offices.

Environmental Engineering Honors Program

Students interested in pursuing an honors program should contact the undergraduate program director of Biological and Environmental Engineering or the associate director of Civil and Environmental Engineering for information on the program requirements.

SCIENCE OF EARTH SYSTEMS

Offered by the Department of Earth and Atmospheric Sciences

Contact: 2124 Snee Hall, 255-5466, www.eas.cornell.edu

We live on a planet with finite resources and a finite capacity to recover quickly from human-induced environmental stresses. Natural hazards such as earthquakes, hurricanes, and volcanic eruptions can alter the course of history with little prior warning. As the human population grows, understanding the earth and its resources becomes progressively more important to both future policymakers and ordinary citizens, who must find new sources of energy and sustain the quality of our environment. Because the human need to understand the earth is so pervasive and the earth system is so multifaceted, the major covers the spectrum of modern earth sciences, including the structure, composition, and evolution of our planet; the planetary processes producing weather and climate; and processes on and near the earth's surface where the interactions of water, life, rock, and air produce our planetary environment.

The major is built on a rigorous introduction to this broad spectrum plus a concentration chosen by the student to obtain expertise in an area of interest and relevance to the student's career plans.

The major prepares students for a number of career paths including further graduate study in geology, geophysics, geochemistry, biogeochemistry, atmospheric sciences, ocean sciences, hydrology, or environmental sciences and engineering. Careers dealing with energy and mineral resources, natural hazards, weather and climate, ocean sciences, or environmental sciences are possible in academic research groups, governmental agencies, and the private sector. The major also prepares students for careers in environmental policy, law or medicine, science in the media, and K–12 science teaching.

Requirements for the Major

The Engineering College Science of Earth Systems major has the same requirements as the Science of Earth Systems major in other Cornell undergraduate colleges. The major includes strong preparation in mathematics, physics, chemistry, and biology. A second semester of chemistry (CHEM 208 or CHEM 257) is required with PHYS 214 optional. Two semesters of biology are required (either BIO G 101/103–102/104 or BIO G 109–110). A second semester of biology can be replaced by CHEM 257 if CHEM 208 is also selected.

A required introductory course in earth science is satisfied by EAS 220.

The core courses emphasize the interconnectedness of the earth system, and are founded on the most modern views of the planet as an interactive and ever-changing system. Each crosses the traditional boundaries of disciplinary science. Three courses selected from the following four core courses are required for the major.

EAS 301 Evolution of the Earth System

EAS 303 Biogeochemistry

EAS 304 Interior of the Earth

EAS 305 Climate Dynamics

The concentration is achieved by completion of four intermediate to advanced-level courses (300 level and up) that build on the core courses and have prerequisites in the required basic sciences and mathematics courses. Note that additional basic math and science courses may be required to complete the concentration courses, depending upon the student's choice of concentration. The concentration courses build depth and provide the student with a specific expertise in some facet of Earth system science. Four defined areas of specialization include geology, biogeochemistry, atmospheric sciences, and ocean sciences. Students may also design other concentrations. Examples include planetary science, ecological systems, geohydrology, and soil science. The concentration should be chosen during the junior year or before in consultation with the student's advisor and with approval of the Director of Undergraduate Studies. For concentrations beyond the four first named, approval by the SES Curriculum Committee is needed.

Exposure to the basic observations of earth science, whether directly in the out-of-doors, or indirectly by the many advanced techniques of remote sensing of our planet, or in the laboratory, is necessary to understand fully the chosen area of concentration in the major. Three credits of appropriate course work are required. Possibilities include the following:

Courses in the Hawaii Environmental Semester Program; or

Courses given by the Shoals Marine Laboratory; or

EAS 250 Meteorological Observations and Instruments; or

EAS 352 Synoptic Meteorology I; or

EAS 417 Field Mapping in Argentina

EAS 437 Geophysical Field Methods; or

EAS 491 and/or EAS 492 Undergraduate Research with appropriate choice of project; or

Field course or courses taught by another college or university (e.g. Semester at Sea).

Students should discuss with their faculty advisor whether the fourth core course listed above or the course used to fulfill the observation/field requirement may also be used to satisfy the concentration.

For more information contact Professor Bryan Isacks, Department of Earth and Atmospheric Sciences, bli1@cornell.edu, or visit www.eas.cornell.edu.

Field Study in Hawaii

Field study is a fundamental aspect of earth system science. Students wishing to increase their field experience may fulfill some of the requirements for the Science of Earth Systems major by off-campus study through the Cornell Earth and Environmental Semester program (EES). The EES program, offered during the spring semester, emphasizes field-based education and research. It is based on the island of Hawaii, an outstanding natural laboratory for earth and environmental sciences. Courses that may be applied to the Science of Earth Systems major include EAS 240, 322, and 351. The EES program also offers opportunities for internships with various academic, nonprofit, and government organizations. Typically, students participate in the EES program during their junior year, although exceptions are possible. For further information, see www.geo.cornell.edu/geology/classes/hawaii/.

Science of Earth Systems Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the requirements of an honors thesis involving research (EAS 491–492 or 499, 2 or more credits each) of breadth, depth, and quality. A written proposal of the honors project must be accepted by the student's advisor and the director of undergraduate studies early in the first semester of the student's senior year.

INDEPENDENT MAJOR

Offered by the Independent Major Committee

Contact: Associate Dean for Undergraduate Programs, 167 Olin Hall, 255-8240

The independent major is designed for students whose educational objectives cannot be met by one of the regular majors. With the exception of certain faculty-sponsored programs, this major consists of an engineering primary area (32 credits) and an educationally related secondary area (16 credits). The primary area may be in any subject area offered by schools or departments of the college; the secondary area may be in a second engineering subject area or in a logically connected nonengineering area. The combination must form an engineering education in scope and substance and should include engineering design and synthesis as well as engineering sciences. Each program includes the normally required common-curriculum requirements and approved electives.

Students should apply to the independent major during the sophomore year. A student should seek assistance in developing a coherent program from professors in the proposed primary and secondary areas (an advisor in each area is required). The program must also be approved by the Independent Major Committee. If approved, the program is the curricular contract to which the student must adhere.

Because no single standardized curriculum exists, the independent major is not accredited by ABET. Independent major students who intend to seek legal licensing as a Professional Engineer should be aware that this nonaccredited degree program will require additional education, work, and/or experience to qualify for eligibility to take the Fundamentals of Engineering examination and may affect acceptance into engineering graduate programs.

INFORMATION SCIENCE, SYSTEMS, AND TECHNOLOGY

Offered jointly by the Department of Computer Science and the School of Operations Research and Information Engineering

Contact: 303 Upson Hall, 255-9837, www.infosci.cornell.edu, or 202 Rhodes Hall, 255-5088, www.orie.cornell.edu

Digital information technologies have become pervasive in science, engineering, manufacturing, business, finance, culture, law, and government, dramatically changing the way people work and live. The proliferation and significance of these new technologies demands a new focus in engineering education—one that remains rigorous and technically oriented but is simultaneously devoted to integrating engineering design, theory, and practice within the social and organizational contexts in which these complex digital information systems are employed.

The information science, systems, and technology (ISST) major studies the design and management of complex information systems. Just as structural engineers and nanofabricators use physics at radically different scales, so also there is a scale difference between the focus of the ISST major and the more traditional, look-under-the-hood majors in computer science and operations research and industrial engineering. Rather than focusing on the computing and communication technologies that underlie digital information systems, the ISST major emphasizes information systems engineering in broad application contexts, where issues at the confluence of information science, technology, and management are the primary concerns.

The ISST major has two options. The management science option educates students in methods for quantitative decision making and their application to information technology as well as the broader role that information technology plays in making these methods effective. Students in the information science option will obtain advanced training in methods for the creation, representation, organization, access, and analysis of information in digital form.

Note: Students may not double major in both CS and ISST or OR&IE and ISST.

Engineering distribution courses

Majors are required to take ENGRD 270 Basic Engineering Probability and Statistics as an engineering distribution course. ENGRD 211 Computers and Programming is required for the major and is recommended as the second engineering distribution course.

Major program

Core courses	*Credits*
Probability, Statistics, and Optimization	
OR&IE 320 Optimization I	3
OR&IE 360 Engineering Probability and Statistics II	3
Information Systems	
INFO 230 Intermediate Design and Programming for the Web	3
OR&IE 311 Information Systems and Analysis	3

INFO 330 Data-Driven Web Applications 3

Economic, Organizational, and Social Context

ECON 301 or 313 Microeconomics 3

One of:

ILROB 175 Behavior, Values, and Performance 3

INFO 245 Psychology of Social Computing 3

ENGRC 335 Communications for Engineering Majors 3

Requirements for the information science option:

1. Three courses from Information Systems (Area II below).
2. One course from Mathematical Modeling in IT (Area III).
3. Three electives, all from either Human-Centered Systems (Area V) or Social Systems (Area VI).
4. Two electives from any of the six areas (INFO 490 may be used to fulfill one of these electives).

Requirements for the management science option:

1. Four courses from Mathematical Models in Management Science (Area I).
2. Three electives, one from each of
   - Information Systems (Area II)
   - Mathematical Modeling in IT (Area III)
   - Information Technology Management Solutions (Area IV)
3. Two electives from any of the six areas (INFO 490 may be used to fulfill one of these electives).

Area I. Mathematical Models in Management Science

OR&IE 350 Financial and Managerial Accounting

OR&IE 361 Introductory Engineering Stochastic Processes I

OR&IE 480 Information Technology

OR&IE 580 Simulation Modeling and Analysis

Area II. Information Systems

CS 419 Computer Networks

INFO 430 Information Retrieval

INFO 431 Web Information Systems

CS 432 Introduction to Database Systems

CS 465 Introduction to Computer Graphics

CS 472 Foundations of Artificial Intelligence

CS 474 Introduction to Natural Language Processing

CS 501 Software Engineering

CS 513 System Security

INFO 530 Architecture of Large-Scale Information Systems

CS 578 Empirical Methods in Machine Learning and Data Mining

Area III. Mathematical Modeling in IT

INFO 372 Explorations in Artificial Intelligence

OR&IE 431 Discrete Models

OR&IE 474 Statistical Data Mining I

CS 478 Machine Learning

OR&IE 483 Applications of Operations Research and Game Theory to IT

ECE 562 Fundamental Information Theory

Area IV. IT Management Solutions

OR&IE 481 Delivering OR Solutions with Information Technology

OR&IE 518 Supply Chain Management

Area V. Human-Centered Systems

PSYCH/COGST 342 Human Perceptions: Applications to Computer Graphics, Art, and Visual Display*

INFO 345 Human-Computer Interaction Design

PSYCH 347 Psychology of Visual Communications

PSYCH 380 Social Cognition*

PSYCH 413 Information Processing: Conscious and Unconscious

PSYCH 416 Modeling Perception and Cognition*

INFO 440 Advanced Human-Computer Interaction Design

INFO 445 Seminar in Computer-Mediated Communication

INFO 450 Language and Technology

DEA 470 Applied Ergonomic Methods

*Students who take PSYCH 342 or 416 may also count their prerequisite, PSYCH 205 or 214. Students who take PSYCH 380 may also count PSYCH 280. At most one of these 200-level prerequisites can be counted.

Area VI. Social Systems

INFO 204 Networks

SOC 304 Social Networks and Social Processes

INFO 320 New Media and Society

AEM 322 Technology, Information, and Business Strategy*

INFO 349 Media Technologies

INFO 355 Computers: From the 17th Century to the Dot.com Boom

INFO 356 Computing Cultures

INFO 366 History and Theory of Digital Art

ECON 368 Game Theory (formerly ECON 467)*

INFO 387 The Automatic Lifestyle: Consumer Culture and Technology

S&TS 411 Knowledge, Technology, and Property

INFO 415 Environmental Interventions

ECON 419 Economic Decisions Under Uncertainty

INFO 429 Copyright in the Digital Age

INFO 435 Seminar on Applications of Information Science

OR&IE 435 Introduction to Game Theory*

S&TS 438 Minds, Machines, and Intelligence

INFO 444 Responsive Environments

INFO 447 Social and Economic Data

H ADM 474 Strategic Information Systems*

ECON 476/477 Decision Theory I and II

H ADM 489 The Law of the Internet and E-Commerce

INFO 515 Culture, Law, and Politics of the Internet

*Only one of ECON 368 and OR&IE 435 may be taken for ISST credit. Only one of AEM 322 and H ADM 474 may be taken for ISST credit.

Information Science, Systems, and Technology Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the following requirements.

1. 4 credit hours of ISST course work at or above the 500 level (no S-U courses; no seminars or 2-credit courses)
2. 6 credit hours of INFO 490 independent study and research with an ISST faculty member, spread over at least two semesters, with at least A– each semester

   or

   3 credit hours of INFO 490 independent study and research with an ISST faculty member and 3 credit hours of INFO 491 teaching experience, both with grades of at least A–.

The ISST research is expected to result in a programming project or a written report (or both).

Any 500- or 600-level course taken to fulfill the honors requirements may not be counted toward fulfillment of the associated primary or secondary option requirements.

Procedures

Each program must be approved by the appropriate co-director of the ISST major, and any changes to the student's program must also be approved.

MATERIALS SCIENCE AND ENGINEERING

Offered by the Department of Materials Science and Engineering

Contact: 214 Bard Hall, 255-9159, www.mse.cornell.edu

This major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Prospective majors are required to take ENGRD 261 or 262 before affiliating with the major. It is highly recommended that the course be taken as an engineering distribution during the sophomore year.

The major program develops a comprehensive understanding of the physics and chemistry underlying the unique properties of modern engineering materials and processes.

Students are required to complete a series of electives to develop knowledge of materials, such as biomaterials, ceramics, polymers, and semiconductors. Application-related courses include areas of biotechnology and life science, energy and environment, materials for information science, nanotechnology, and technology management and ethics. These requirements are satisfied through a series of technical electives taken mainly in the senior year, which are selected from various engineering and science departments. Optional research involvement courses provide undergraduates with the opportunity to work with faculty members and their research groups on current projects.

The major requirements for a B.S. degree in materials science and engineering are:

1. ENGRD 261 Mechanical Properties of Materials: From Nanodevices to Superstructures *or*

   ENGRD 262 Electronic Materials for the Information Age

2. 13 required major courses:

   MS&E 206 Atomic and Molecular Structure of Matter

   MS&E 261 or MS&E 262 (whichever was not taken as a distribution course)

   MS&E 301 Materials Chemistry

   MS&E 303 Thermodynamics of Condensed Systems

   MS&E 304 Kinetics, Diffusion, and Phase Transformations

   MS&E 305 Electronic, Magnetic, and Dielectric Properties of Materials

   MS&E 307 Materials Design Concepts I

   MS&E 311 Junior Lab I

   MS&E 312 Junior Lab II

   MS&E 402 Mechanical Properties of Materials, Processing, and Design

   MS&E 403/405 Senior Materials Lab I or Senior Thesis I

   MS&E 404/406 Senior Materials Lab II or Senior Thesis II

   MS&E 407 Materials Design Concepts II

3. Two materials-related electives covering two groups of different materials

4. Three application-related electives in at least two different types of applications

5. Two of the application-related electives must be taken from outside MS&E

6. One additional technical elective outside MS&E

Materials Science and Engineering Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the following requirements.

1. The 9 credits (giving a total of 141) of additional courses must be technical in nature, i.e., in engineering, math, chemistry, and physics at the 400 and graduate level, with selected courses at the 300 level. The courses must be approved by the major advisor.

2. Senior honors thesis (MS&E 405/406) with a grade of at least A.

MECHANICAL ENGINEERING

Offered by the Sibley School of Mechanical and Aerospace Engineering

Contact: 108 Upson Hall, 255-3573, maeng@cornell.edu, www.mae.cornell.edu

This major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

This major is designed to provide a broad background in the fundamentals of the discipline as well as to offer an introduction to the many professional and technical areas in which mechanical engineers work. The program covers both major streams of mechanical engineering.

(1) *Mechanical systems, design, and materials processing* is concerned with the design, analysis, testing, and manufacture of machinery, vehicles, devices, and systems. Other topics covered are computer-aided design, vibrations, control systems, and dynamics. Particular areas of concentration are mechanical systems and design, vehicle engineering, biomechanics, and engineering materials.

(2) *Engineering of fluids, energy, and heat-transfer systems* is concerned with the efficient conversion of energy, aerospace and surface transportation, the environmental impact of engineering activity (including pollutants and noise), aeronautics, and the experimental and theoretical aspects of fluid flow, heat transfer, thermodynamics, and combustion. Specific areas of concentration include aerospace engineering and thermo-fluids engineering.

During the fall semester, sophomores who plan to affiliate with the mechanical engineering major take ENGRD 202 (also T&AM 202) as an engineering distribution course. ENGRD 221/M&AE 221 is required for the major and is recommended as the second engineering distribution course. The Sibley School supports students who have unusual requirements, but delays or substitutions must be discussed with and receive approval from their major advisor.

The major requires 13 courses (beyond ENGRD 202 already mentioned) and five major-approved elective courses.

Required courses

M&AE 212 Mechanical Properties and Selection of Engineering Materials

ENGRD 221 Thermodynamics

M&AE 225 Mechanical Synthesis

ENGRD 203 Dynamics

M&AE 378 Mechatronics *or* ENGRD 210 Introduction to Electrical Circuits, Electrical and Computer Engineering, or PHYS 360 Electronic Circuits

M&AE 323 Introductory Fluid Mechanics

M&AE 324 Heat Transfer

M&AE 325 Analysis of Mechanical and Aerospace Structures

M&AE 326 System Dynamics

M&AE 327 Mechanical Property and Performance Laboratory

M&AE 427 Fluids/Heat Transfer Laboratory

M&AE 428 Engineering Design

M&AE 429 Supervised Senior Design Experience

Electives

Students should use the flexibility provided by the major-approved electives, advisor-approved electives, and humanities, arts, and social sciences electives to develop a program to meet their specific goals.

Major-approved electives

The major includes five major-approved electives. At least three of these courses must be upper-level (300+) M&AE courses. Of these three, two must be a concentration of M&AE's upper-level courses providing depth in a specific subject area. Standard concentrations are shown below, but students may petition for approval of two other related courses to form a custom concentration.

The standard concentrations are:

Aerospace engineering, M&AE 305, 306, 415, 423, 506, 507

Biomechanics, M&AE 464, 466

Engineering materials, M&AE 312, 313, 455, 464, 470, 513

Mechanical systems and design, M&AE 378*, 409, 415, 417, 470, 477, 478, 479, 514

Thermo-fluids engineering, M&AE 423, 449, 453, 501, 543

Vehicle engineering, M&AE 305, 306, 425, 449, 486, 506, 507

*Students who took M&AE 378 as a required course (see above) may not use it again as a major-approved elective.

One major-approved elective must be a senior design elective involving M&AE 429 "Supervised Senior Design Experience." One way to satisfy this requirement is to take a 3+ credit section of M&AE 429, directed by a faculty member as a individual or team exercise. The other option is to take a senior design elective course (M&AE 400, 423, 425, 470, 479, or 489) along with the corresponding 1-credit section of M&AE 429.

One of the major-approved electives must be an approved upper-level math course taken after MATH 294. The course must include some statistics. Currently, the approved courses are T&AM 310, ENGRD 270, CEE 304, and ENGRD 320.

One of the major-approved electives, the "technical elective," may be any course at an appropriate level, chosen from engineering, math, or science (physics, chemistry, or biological sciences). Appropriate level is interpreted as being at a level beyond the required courses of the college curriculum. Courses in economics, business, and organizational behavior are not accepted. Advisors may approve such courses as advisor-approved electives.

*M&AE 498 may not be used as a major-approved elective.

Advisor-approved electives

To maximize flexibility (i.e., the option for study abroad, Co-op, internships, pre-med, and flexibility during the upper-class years), the Sibley School faculty recommends that students delay use of advisor-approved (AA) electives until after the third semester.

Students must seek advisor approval before taking an AA elective. Advanced placement credit may not count as an AA elective. Up to 6 credits of Reserve Officer Training Corps (ROTC) courses numbered 300 or above or co-listed in an academic department are allowed as AA electives. Students must document AA electives approved before M&AE affiliation within a month of registration as an M&AE student. The faculty encourages students to consider the following as possible AA electives:

- an engineering distribution course
- courses stressing oral or written communications
- courses stressing the history of technology
- rigorous courses in the physical sciences (physics, biology, chemistry)
- courses in information science (mathematics, computer science)
- courses in methodologies (modeling, problem solving, synthesis, design)
- courses in technology (equipment, machinery, instruments, devices, processes)
- courses in business enterprise operations (e.g., economics, financial, legal)
- courses in organizational behavior
- courses in cognitive sciences

Other considerations

It is recommended that humanities, arts, and social sciences electives include studies in:

- history of technology
- societal impacts of technology
- history
- foreign languages
- ethics
- communications
- political science
- aesthetics
- economics
- architecture

The Sibley School encourages its students to spend a junior year abroad at foreign universities with which the college has an exchange agreement, such as the Ecole Centrale de Paris.

The technical-writing requirement of the common curriculum is satisfied by M&AE 427.

A limited set of third-year courses is offered each summer under the auspices of the Engineering Cooperative Program.

Preparation in Aerospace Engineering

There is no separate undergraduate accredited program in aerospace engineering, but students may prepare for a career or graduate program in this area by majoring in mechanical engineering and taking courses from the aerospace engineering minor or concentration, for example spacecraft engineering, introduction to aeronautics, and aerospace propulsion systems. It is also possible to prepare for a career or graduate program in aerospace engineering through appropriate course selection in other majors, for example: electrical and computer engineering, engineering physics, or the physical sciences. Other subjects recommended as preparation for aerospace engineering endeavors include thermodynamics, fluid mechanics, structures, vibrations, feedback controls, applied mathematics, chemistry, and physics.

OPERATIONS RESEARCH AND ENGINEERING

Offered by the School of Operations Research and Information Engineering

Contact: 203 Rhodes Hall, 255-5088, www.orie.cornell.edu

This major provides a broad education in the techniques and modeling concepts needed to analyze and design complex systems and an introduction to the technical and professional areas of operations research and industrial engineering. The major prepares students for a wide range of careers including operations research, industrial engineering, entrepreneurship, information technology, operations management, consulting, financial engineering, financial services, and management.

The foundation of the major is the development of basic skills in calculus, statistics, probability, mathematical optimization, and computer science. Required courses in manufacturing systems, cost accounting, and simulation build on these skills and provide engineering design experiences. In the senior year the curriculum is quite flexible. Students take OR&IE electives to broaden and deepen their expertise in applied probability and statistics, industrial systems, optimization, information technology, or financial engineering.

Because of the wide range of career goals among ORE students, the major is designed with a minimum of required courses and a large number of required electives. Students should consult with their major advisors to select electives that best meet their future goals.

Exceptional students interested in pursuing graduate studies are encouraged to speak with their faculty advisors concerning an accelerated program of study.

A student who intends to affiliate with the major in operations research and engineering should take ENGRD 270 Basic Engineering Probability and Statistics after completing MATH 192; MATH 294 should be completed before or concurrently with ENGRD 270. ORE affiliates are required to complete MATH 191, 192, and 294 (or their subject matter equivalents.) Either MATH 293, CS 280, or MATH 304 can be used to satisfy the fourth-semester mathematics requirement. Students should discuss with their advisors which of these three courses is most appropriate to their future program of study in ORE. The following considerations should be borne in mind.

1. MATH 293 (differential equations) is essential for advanced study in financial engineering. Also, MATH 293 is a prerequisite for PHYS 214, thus students who do not take MATH 293 must plan to take CHEM 208.
2. CS 280 provides an introduction to discrete structures and algorithms of broad applicability in the field of operations research, particularly for fundamental models in the areas of optimization, production scheduling, inventory management, and information technology; it is also a prerequisite for certain upper-class Computer Science courses in the areas of information technology and algorithmic analysis.
3. MATH 304 covers fundamentals of formal proof techniques; this material is strongly recommended for students who intend advanced (PhD-level) study in Operations Research or a related field.

Early consultation with a faculty member or the associate director for undergraduate studies can be helpful in making appropriate choices.

The required courses for the ORE major and the typical terms in which they are taken are as follows:

Semester 2 or 3	*Credits*
ENGRD 211 Computers and Programming	3
ENGRD 270 Basic Engineering Probability and Statistics	3
Semester 4	
OR&IE 312 Industrial Data and Systems Analysis*	4
Semester 5	
OR&IE 320 Optimization I	4
OR&IE 360 Engineering Probability and Statistics II	4
Behavioral Science (Organizational Behavior)†	3
Humanities/social sciences elective	3
Major-approved elective	3
Semester 6	
OR&IE 350 Financial and Managerial Accounting (may be taken in semester 4)	
OR&IE 321 Optimization II	4
OR&IE 361 Introductory Engineering Stochastic Processes I	4
Advisor-approved elective	3
Humanities/social sciences elective	3

*It is highly recommended that OR&IE 312 be taken in semester 4. If the student's schedule does not permit this, the course may be taken in semester 6 or 8.

†The behavioral science requirement can be satisfied by any of several courses, including the Johnson Graduate School of Management (JGSM) course NCC 554 (offered only in the fall), which is recommended for those contemplating the pursuit of a graduate business degree, ILROB 121, and 175, H ADM 115, ENGRC 335 (which also satisfies the technical writing requirement), and others.

The basic senior-year program, from which individualized programs are developed, consists of the following courses:

Minimum credits	
OR&IE 580 Monte Carlo Simulation	2
OR&IE 581 Discrete-Event Simulation	2
Three upper-class OR&IE electives as described below	9
Two major-approved electives (at least 3 credits must be outside OR&IE)	6
Two humanities/social sciences electives	6
One advisor-approved elective	3

Available OR&IE electives are as follows:

Manufacturing and distribution systems: OR&IE 416, 451, 480, 481, 483, 518, 525, and 562 and JGSM NBA 641

Optimization methods: OR&IE 431, 432, 434, 435, 436, 437, and 533

Applied probability and statistics: OR&IE 462, 464, 474, 476 (2 credits), 561, 563, 574, 575 (2 credits), 576 (2 credits), and 577

Financial engineering: OR&IE 468, 473, 567, 568, 569, and 573

Academic Standing

The student in the major should obtain a passing grade in every course; at least C– in ENGRD 211 and 270, OR&IE 312, 320, 321, 350, 360, 361, 580, and 581; a GPA of 2.0 each semester; a GPA of 2.0 for ORE major courses; and satisfactory progress toward completion of the degree requirements. Each student's performance is reviewed at the conclusion of each semester.

If at least C– is not earned in a required course, the course must be repeated within one year before the next course in the sequence may be taken (OR&IE 321 and 361, in particular). Failure to achieve at least C– in the second attempt will generally result in withdrawal from the major.

Operations Research and Engineering Honors Program

The B.S. degree with honors is granted to engineering students who satisfy the requirements given at the beginning of the section "Engineering Majors" as well as the following requirements.

The 9 additional credits of course work shall be from one or more of the following, with at least 4 credits in the first category:

1. Advanced courses in OR&IE at the 500 level or above.
2. A significant research experience or honors project under the direct supervision of an OR&IE faculty member using OR&IE 499 OR&IE Project. A significant written report must be submitted as part of this component.
3. A significant teaching experience under the direct supervision of a faculty member in OR&IE using OR&IE 490 Teaching in OR&IE or ENGRG 470 Undergraduate Engineering Teaching.

Procedures

Each program must be approved by the associate director of undergraduate studies, and any changes to a program must be approved by the associate director.

ENGINEERING MINORS

The engineering minor is a supplement to the B.S. degree majors in the college, including the independent major. It recognizes formal study of a particular subject area in engineering normally outside the major. Students undertaking a minor are expected to complete the requirements during the time of their continuous undergraduate enrollment at Cornell. Completing the requirements for an engineering minor (along with a major) may require more than the traditional eight semesters at Cornell. However, courses that fulfill minor requirements may also satisfy other degree requirements (e.g., distribution courses, advisor-approved, or major-approved electives), and completion within eight semesters is possible.

An engineering minor requires:

- successful completion of all requirements for a B.S. degree in engineering.
- enrollment in an engineering major that approves participation in the minor.
- satisfactory completion of six courses (at least 18 credits) in a college-approved minor.

Students may apply for certification of an engineering minor at any time after the required course work has been completed in accordance with published standards. An official notation of certification of a minor appears on the Cornell transcript following graduation.

The College of Engineering offers minors in the following areas (offering units are indicated in parentheses):

Aerospace Engineering (M&AE)

Applied Mathematics (T&AM)

Biological Engineering (BEE)

Biomedical Engineering (BME)

Civil Infrastructure (CEE)

Computer Science (CS)

Electrical and Computer Engineering (ECE)

Engineering Management (CEE)

Engineering Statistics (OR&IE)

Environmental Engineering (BEE/CEE)

Geological Sciences (EAS)

Game Design (CS)

Industrial Systems and Information Technology (OR&IE)

Information Science (INFO)

Materials Science and Engineering (MS&E)

Mechanical Engineering (M&AE)

Operations Research and Management Science (OR&IE)

Additional information on specific minors can be found below, in the *Engineering Undergraduate Handbook*, in the undergraduate major office of the department or school offering the minor and in Engineering Advising.

MINOR: AEROSPACE ENGINEERING

Offered by: Sibley School of Mechanical and Aerospace Engineering

Administered by M&AE associate director, 108 Upson Hall, 255-3573, np18@cornell.edu

Contact: 108 Upson Hall, 255-3573, www.mae.cornell.edu

Students should consult the M&AE web site (www.mae.cornell.edu) for the most up-to-date list of majors eligible to participate in the Aerospace Engineering minor. Mechanical Engineering majors may participate in this minor. Students intending to earn this minor should seek advice and pre-approval of their minor academic program from the associate director for undergraduate affairs in Mechanical Engineering before taking courses toward the minor.

The aerospace engineering minor develops the engineering analysis and design skills necessary for creating and understanding aerospace vehicles and their subsystems. The minor includes diverse topics relevant to applications both in the earth's atmosphere (e.g., aerodynamics) and in space (e.g., spacecraft thermal systems or orbital mechanics). Students in this minor will take at least four core aerospace courses, along with up to two supporting courses in engineering fundamentals or courses with applicability to aeronautics and spacecraft.

Academic Standards: A grade of at least C- in each course. If a course is offered only S-U, a grade of S is acceptable.

Requirements:

Six courses from the lists below, each worth at least 3 credits, must be completed. No substitutions will be accepted from other departments at Cornell or elsewhere.

Rules for selecting courses:

1. Rules for ME majors:

a. Select least four courses from group A, of which you must choose M&AE 305 or M&AE 306 (or both).

b. Select at most two courses from group B. No courses from group C may be used.

c. Use at most four courses to satisfy both the Aerospace Minor requirements and the BSME degree requirements. The major concentration courses may not be among these overlapped courses.

2. Rules for other majors:

a. Select least four courses from group A, of which you must choose M&AE 305 or M&AE 306 (or both).

b. Select a total of at most two courses from group B and group C.

c. Do not use any courses to satisfy requirements of both the Mechanical Engineering Minor and the Aerospace Engineering Minor.

Group A: Core Aerospace Engineering

M&AE 305 Intro to Aeronautics

M&AE 306 Spacecraft Engineering

M&AE/ECE 415 GPS: Theory and Design

*M&AE 429 Supervised Senior Design Experience, with Aerospace Focus or M&AE 490 Special Investigations in Mechanical and Aerospace Engineering, with Aerospace Focus

M&AE 423/523 Intermediate Fluid Dynamics

M&AE 506 Aerospace Propulsion Systems

M&AE 507 Dynamics of Flight Vehicles

*M&AE 429 and 490 require a form signed by the project advisor, stating that the project focuses on aerospace and is suitable as a core aerospace course for the minor. M&AE 429 or 490 must be worth 3 credits or more. Students are restricted to at most one M&AE 429 OR one M&AE 490 counting toward the minor (may not count both M&AE 429 and M&AE 490 toward the minor).

Group B: Courses Applicable to Aerospace Engineering

M&AE 417/517 Introduction to Robotics: Dynamics, Control, Design

M&AE 455/CEE 477/MS&E 555/T&AM 455 Introduction to Composite Materials

M&AE 470/570 Finite Element Analysis for Mechanical and Aerospace Design or CEE 472 Introduction to the Finite Element Method

M&AE 477/577 Engineering Vibrations

M&AE 478/578/CHEME 472/ECE 472 Feedback Control Systems

M&AE 479/579 Modeling and Simulation of Mechanical and Aerospace Systems

M&AE 543 Combustion Processes

M&AE 571 Applied Dynamics or T&AM 570 Intermediate Dynamics

Group C: Fundamentals

ENGRD 202

ENGRD 203

M&AE 212

ENGRD/M&AE 221

M&AE 323

M&AE 324

M&AE 325

M&AE 326

M&AE 378 or ECE 210/ENGRD 210

MINOR: APPLIED MATHEMATICS

Offered by the Department of Theoretical and Applied Mechanics

Contact: Richard Rand, 207 Kimball Hall, 255-7145, rhr2@cornell.edu, www.tam.cornell.edu/Undergrad.html

All engineering undergraduates are eligible to participate in this minor.

Academic standards: At least C in each course in the minor.

Requirements

At least six courses beyond MATH 294, to be chosen as follows:

a. At most one course from any one of the groups 1, 2, 3, or 4.

b. At least three courses from groups 5 and 6.

c. At most one 200-level course.

d. At most one course that is offered by the student's major department.

1. Analysis

   T&AM 310 Introduction to Applied Mathematics I

   MATH 321 Manifolds and Differential Forms

   MATH 420 Differential Equations and Dynamical Systems

   A&EP 321 Mathematical Physics I

2. Computational Methods

   ENGRD 322 Introduction to Scientific Computation

   ENGRD 320 Engineering Computation

   OR&IE 320 Optimization I

   CS 421 Numerical Analysis

3. Probability and Statistics

   ENGRD 270 Basic Engineering Probability and Statistics

   OR&IE 360 Engineering Probability and Statistics II

   ECE 310 Introduction to Probability and Random Signals

   CEE 304 Uncertainty Analysis in Engineering

   MATH 471 Basic Probability

4. Applications

   A&EP 333 Mechanics of Particles and Solid Bodies

   CHEME 323 Fluid Mechanics

   CEE 331 Fluid Mechanics

   CEE 371 Modeling of Structural Systems

   CS 280 Discrete Structures

   CS 285 Networks

   ECE 320 Networks and Systems

   ECE 425 Digital Signal Processing

   MS&E 303 Thermodynamics of Condensed Systems

   M&AE 323 Introductory Fluid Mechanics

5. Advanced courses

   Only one of these three may be chosen:

   T&AM 311 Introduction to Applied Mathematics II

   MATH 422 Applied Complex Analysis

   A&EP 322 Mathematical Physics II

   Only one of the following two may be chosen:

   ECE 411 Random Signals in Communications and Signal Processing

   OR&IE 361 Introductory Engineering Stochastic Processes I

   Only one of the following two may be chosen:

   CS 381 Introduction to Theory of Computing

   CS 481 Introduction to Theory of Computing

   Only one of the following two may be chosen:

   M&AE 571 Applied Dynamics

   T&AM 570 Intermediate Dynamics

   Also, you may choose from:

   CS 428 Introduction to Computational Biophysics

   CS 482 Introduction to the Design of Algorithms

   OR&IE 321 Optimization II

   OR&IE 431 Discrete Models

   OR&IE 435 Introduction to Game Theory

   OR&IE 462 Introductory Engineering Stochastic Processes II

   OR&IE 568 Financial Engineering with Stochastic Calculus I

   OR&IE 569 Financial Engineering with Stochastic Calculus II

   T&AM 578 Nonlinear Dynamics and Chaos

   T&AM 610 Methods of Applied Mathematics I

   T&AM 611 Methods of Applied Mathematics II

6. Mathematics courses

   Any 300+ level course offered by the Mathematics Department in algebra, analysis, probability/statistics, geometry, or logic, with the following exceptions:

   a. MATH 323 or 420, if any course from group 1 is chosen

   b. MATH 471, if any course from group 3 is chosen

   c. MATH 422, if T&AM 311 or A&EP 322 is chosen from group 5

   d. Only one of the following may be chosen:

   MATH 332 Algebra and Number Theory

   MATH 335 Introduction to Cryptology

   MATH 336 Applicable Algebra

MINOR: BIOLOGICAL ENGINEERING

Offered by the Department of Biological and Environmental Engineering

Contact: 207 Riley-Robb Hall, 255-2173, www.bee.cornell.edu

Students in all majors except biological engineering may participate. Students should meet with the BE coordinator as soon as they decide to pursue the minor and before their senior year. They will work with a BEE faculty advisor, who will assist them in completing their minor.

Educational objectives of the minor:

Biological engineering is the application of engineering to living systems. Examples of engineering efforts in this field include the development of new biosensor technologies, study and control of biologically based matter transformation systems, and development of engineered devices to study and regulate fundamental biological processes. The biological engineering minor is an opportunity for students to further their understanding of living systems and to increase their knowledge of the basic transport processes that occur within these systems. Courses in the minor provide opportunities to analyze and manipulate living systems at the molecular, cellular, and system levels.

Academic standards: At least C– in each course in the minor and a GPA $\geq$ 2.0 in all courses in the minor

Requirements

At least six courses ($\geq$ 18 credits), with at least three courses and 9 credits taught in BEE as follows:

BEE 350 Biological and Environmental Transport Processes (3 credits): required

I. **Biology Foundation** (at least one but no more than two courses)

BIOBM 330 or 331–332 Biochemistry

BIOMI 290 Microbiology

BIONB 222 Neurobiology

II. **Biological Engineering Core** (at least one but no more than two courses)

BEE 260 Principles of Biological Engineering

BEE 350 Biological and Environmental Transport Processes

BEE 360 Molecular and Cellular Bioengineering

BEE 331 Bio-fluid Mechanics

III. **Biological Engineering Concentration Electives** (minimum of 3 courses)

Choose any three courses from the concentration lists below. Courses appearing in more than one concentration do not double count. BEE 360 may be taken as either a concentration elective or a core course.

Biomedical Engineering Concentration

A&EP 470 Biophysical Methods

BEE 360 Molecular and Cellular Bioengineering

BEE 365 Properties of Biological Materials

BEE 450 Bioinstrumentation

BEE 453 Computer-Aided Engineering: Applications to Biomedical Processes

BEE 454 Physiological Engineering

BEE 459 Biosensors and Bioanalytical Techniques

BME 330 Introduction to Computational Neurosciences

BME 402 Biomedical System Design

BME 440 Electronics in Neurobiology

BME 539 Biomedical Materials and Devices for Human Body Repair

BME 565 Biomechanical Systems—Analysis and Design

CHEME 481 Biomedical Engineering

ECE 578 Computer Analysis of Biomedical Processes

M&AE 401 Biomedical Engineering Analysis

M&AE 463 Neuromuscular Biomechanics

M&AE 464 Orthopaedic Tissue Mechanics

MS&E 461 Biomedical Materials and their Applications

Bioprocess Engineering Concentration

BEE 360 Molecular and Cellular Bioengineering

BEE 450 Bioinstrumentation

BEE 453 Computer Aided Engineering: Applications to Biomedical Processes

BEE 459 Biosensors and Bioanalytical Techniques

BEE 464 Bioseparation Processes

BEE 484 Metabolic Engineering

CHEM 300 Quantitative Chemistry (does not count for Engineering credit)

CHEME 332 Analysis of Separation Processes

CHEME 543 Bioprocess Engineering

Bioenvironmental Engineering Concentration

BEE 360 Molecular and Cellular Bioengineering

BEE 371 Physical Hydrology for Ecosystems

BEE 435 Principles of Aquaculture

BEE 471 Introduction to Groundwater

BEE 473 Watershed Engineering

BEE 478 Ecological Engineering

BEE 651 Bioremediation Engineering Organisms to Clean up the Environment

CEE 451 Microbiology for Environmental Engineering

CEE 452 Water Supply Engineering

MINOR: BIOMEDICAL ENGINEERING

Offered by the Department of Biomedical Engineering (BME)

Contact: Carol Casler, 120 Olin Hall, 255-1489, www.bme.cornell.edu/academics/undergraduate/biomedminor.cfm

All undergraduates in the College of Engineering, College of Arts and Sciences, College of Human Ecology, and College of Agriculture and Life Sciences are eligible to participate in this minor. Students may participate in only one of these areas of interest: the biological engineering minor or the biomedical engineering minor.

Educational Objectives: Biomedical engineering is the application of engineering principles and methods to a wide array of problems associated with human health. The discipline includes the design of biocompatible materials, prostheses, surgical implants, artificial organs, controlled drug-delivery systems, and wound closure devices. Diagnosing diseases and determining their biological origins depend upon increasingly sophisticated instrumentation and the use of mathematical models. This minor allows students to gain exposure to the breadth and depth of biomedical engineering offerings at Cornell, to prepare for advanced studies in biomedical engineering, and to obtain transcript recognition for their interest and capability in this rapidly growing area.

Students are asked to complete a form declaring their interest in the minor with the biomedical engineering undergraduate minor coordinator in 120 Olin Hall. On the form you will be asked to choose a BME faculty advisor that you can consult about the BME minor plan.

Academic standards: At least C– in each course in the minor. A cumulative GPA ≥ 2.0 for all courses in the minor.

Requirements

The 1-credit Bioengineering Seminar as well as at least six courses (≥ 18 credits) from the five categories listed below; two courses need to be in categories 1. Introductory biology and/or 2. Advanced biology with no more than one course from category 1. Four courses must come from the following categories: 3. Molecular and cellular biological engineering, 4. Biomedical engineering analysis of physiological systems, and 5. Biomedical engineering applications with courses from at least two of these categories. At least four of the six courses must not be specifically required major degree courses or cross-listings.

Required course: BME 501/BEE 501 Bioengineering Seminar (1 credit, 1 semester)

Category 1. Introductory biology (maximum of 4 credits and one course toward the BME minor)

A 5 on AP biology exam

A 4 on AP biology exam and ENGRI 131

A 4 on AP biology exam and BIO G 103 or BIO G 104

BIO G 101, 102, 103, and 104 Biological Sciences

BIO G 105 and 106 Introductory Biology

BIO G 107 and 108 General Biology

BIO G 110 and ENGRI 131 Biological Principles and Introduction to Biomedical Engineering

Category 2. Advanced biology

BIOAP 311/VTBMS 356 Introductory Animal Physiology Lectures

BIOBM 330 Principles of Biochemistry, Individualized Instruction

BIOBM 331 Principles of Biochemistry, Proteins and Metabolism

BIOBM 332 Principles of Biochemistry, Molecular Biology

BIOBM 333 Principles of Biochemistry, Proteins, Metabolism, and Molecular Biology

BIOGD 281 Genetics

BIONB 222 Neurobiology and Behavior II: Introduction to Neurobiology

BIOMI 290 General Microbiology Lectures

Category 3. Molecular and cellular biomedical engineering

A&EP 252/ENGRD 252 The Physics of Life

BEE 360/BME 360 Molecular and Cellular Bioengineering

BME 301/CHEME 401* Molecular Principles of Biomedical Engineering

BME 302/CHEME 402* Cellular Principles of Biomedical Engineering

Category 4. BME analysis of physiological systems

BEE 454 Physiological Engineering

BIONB 330/BME 330/COGST 330/PSYCH 330 Introduction to Computational Neuroscience

BIONB 491/BME 491 Principles of Neurophysiology

BME 401/M&AE 466* Biomedical Engineering of Metabolic and Structural Systems

BME 402* Electrical and Chemical Physiology

CHEME 481/BME 481 Biomedical Engineering

M&AE 464/BME 464 Orthopaedic Tissue Mechanics

Category 5. Biomedical engineering applications

A&EP 470/BIONB 470/BME 570 Biophysical Methods

BEE 365 Properties of Biological Materials

BEE 450 Bioinstrumentation

BEE 453/M&AE 453 Computer-Aided Engineering: Applications to Biomedical Processes

BEE 459 Biosensors and Bioanalytical Techniques

BEE 494 Fundamentals of Tissue Engineering

BIONB 442/BME 442 Instrumentation for Biology

BME 411 Science and Technology Approaches to Problems in Human Health

CS 321/BIOBM 321/ENGRD 321 Numerical Methods in Computational Molecular Biology

ECE 402/BME 404 Biomedical System Design

ECE 578 Computer Analysis of Biomedical Images

M&AE 565/BME 565 Biomechanical Systems—Analysis and Design

MS&E 461 Biological Materials and Their Applications

MS&E 541/ECE 336 Nanofabrication

MS&E 562/BME 562 Biomineralization: The Formation and Properties of Inorganic Biomaterials

FSAD 439/BME 539 Biomedical Materials and Devices for Human Body Repair

*Students interested in professional practice as biomedical engineers should consider an M.Eng. degree in BME. The recommended sequence for admission is as follows: two courses from categories 1 and 2, BME 301, 302, 401, and 402. The program requires students to have a knowledge of molecular and cellular biomedical engineering, and of biomedical engineering analysis of physiological systems.

MINOR: CIVIL INFRASTRUCTURE

Offered by the School of Civil and Environmental Engineering

Contact: 221 Hollister Hall, 255-3412, www.cee.cornell.edu

Students affiliated with all majors except civil engineering are eligible to participate in this minor.

The minor in civil infrastructure is intended to introduce engineering undergraduates to the engineering methodologies of mechanics, materials, analysis, design, and construction and to show how these are used in solving problems in the development, maintenance, and operation of the built environment that is vital for any modern economy.

Academic standards: At least C in each course in the minor

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. Required course: ENGRD 202 Mechanics of Solids
2. Additional courses: choose any five (groupings are for information only)*

Geotechnical engineering

CEE 341 Introduction to Geotechnical Engineering

CEE 440 Foundation Engineering

CEE 441 Retaining Structures and Slopes

CEE 444 Environmental Site and Remediation Engineering

Structural engineering

CEE 371 Structural Modeling and Behavior

CEE 372 Intermediate Solid Mechanics

CEE 471 Fundamentals of Structural Mechanics

CEE 472 Introduction to the Finite Element Method

CEE 473 Design of Concrete Structures

CEE 474 Design of Steel Structures

CEE 478 Structural Dynamics and Earthquake Engineering

Other related courses

CEE 595 Construction Planning and Operations

*Other CEE courses may be approved by petition in advance

MINOR: COMPUTER SCIENCE

Offered by the Department of Computer Science

Contact: 303 Upson Hall, 255-0982, www.cs.cornell.edu

Students affiliated with all engineering majors except Computer Science are eligible to participate in this minor. This minor is for students who anticipate that computer science will play a prominent role in their academic and professional career.

Academic standards: At least C in each course in the minor.

Requirements

At least six courses (18 credits) chosen as follows:

1. Required courses

   CS/ENGRD 211 Computers and Programming

   One of the following:

   CS 321 Numerical Methods in Computational Molecular Biology,

   CS/ENGRD 322 Introduction to Scientific Computing,

   CS 421 Numerical Analysis and Differential Equations, *or*

   CS 422 Numerical Analysis: Linear and Nonlinear Problems

   CS 428 Introduction to Computational Biophysics.

   CS/ECE 314 Computer Organization, *or*

   CS 316 Systems Programming

2. Additional courses

   Three CS courses numbered 300 or higher with the following exceptions:

   CS 490 and seminars are excluded

   CS 280 is allowed

Cross-listed courses cannot be applied to the minor unless taken under the CS rubric, with the sole exception of ECE 314. All qualifying courses must be taken at Cornell for a letter grade. No substitutions allowed.

MINOR: ELECTRICAL AND COMPUTER ENGINEERING

Offered by the School of Electrical and Computer Engineering

Contact: 223 Phillips Hall, 255-4309, www.ece.cornell.edu

Students affiliated with all majors except Electrical and Computer Engineering are eligible to participate in this minor, but MS&E students must receive prior written approval from both MS&E and ECE, via petition.

This minor offers the opportunity to study analog and digital circuits, signals and systems, and electromagnetics and to concentrate at higher levels in one of several different areas such as circuit design, electronic devices, communications, computer engineering, networks, and space engineering.

Academic standards: At least C– in each course in the minor. GPA ≥ 2.3 for all courses in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. Two of the following:

   ECE/ENGRD 210 Introduction to Circuits for Electrical and Computer Engineers

   ECE 220 Signals and Information

   ECE/ENGRD 230 Introduction to Digital Logic Design

2. Two of the following:

   ECE 303 Electromagnetic Fields and Waves

   ECE/CS 314 Computer Organization

   ECE 315 Introduction to Microelectronics

   ECE 320 Networks and Systems

3. One other ECE course at the 300 level or above (3-credit minimum)
4. One other ECE course at the 400 level or above (3-credit minimum)

MINOR: ENGINEERING MANAGEMENT

Offered by the School of Civil and Environmental Engineering

Contact: 221 Hollister Hall, 255-3412, www.cee.cornell.edu

Students affiliated with all majors are eligible to participate in this minor. CEE students may not use courses simultaneously to satisfy a requirement for the minor and as a major-approved elective or design elective. ORIE students have some specific restrictions and requirements as noted below.

This minor focuses on giving engineering students a basic understanding of engineering economics, accounting, statistics, project management methods, and analysis tools necessary to manage technical operations and projects effectively. The minor provides an important set of collateral skills for students in any engineering discipline.

Academic standards: At least C in each course in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. Required courses (3):

    CEE 323 Engineering Economics and Management

    or OR&IE 451 Economic Analysis of Engineering Systems

    OR&IE 350 Financial and Managerial Accounting[1]

    CEE 304 Uncertainty Analysis in Engineering[2]

    or ENGRD 270 Basic Engineering Probability and Statistics

    or ECE 310 Introduction to Probability and Random Signals

2. Additional courses—choose any three[3]

    CEE 406 Civil Infrastructure Systems

    CEE 492 Engineers for a Sustainable World: Engineering in International Development

    CEE 593 Engineering Management Methods[4]

    CEE 594 Economic Methods for Engineering and Management[4]

    CEE 595 Construction Planning and Operations

    CEE 596 Management Issues in Forensic Engineering

    CEE 597 Risk Analysis and Management

    CEE 598 Introduction to Decision Analysis

    NBA 507 Entrepreneurship for Scientists and Engineers

    or M&AE/ENGRG 461/OR&IE 452 Entrepreneurship for Engineers

    or BEE 489 Engineering Entrepreneurship, Management and Ethics

[1]OR&IE students must substitute NCC 556 or NBA 500 for OR&IE 350

[2]T&AM 310 cannot be substituted for CEE 304

[3]Other courses approved by petition in advance

[4]This course is not accepted for OR&IE students

MINOR: ENGINEERING STATISTICS

Offered by the School of Operations Research and Information Engineering

Contact: 203 Rhodes Hall, 255-5088, www.orie.cornell.edu

Students affiliated with all majors except Operations Research and Engineering are eligible to participate in this minor.

The goal of the minor is to provide the student with a firm understanding of statistical principles and engineering applications and the ability to apply this knowledge in real-world situations.

Academic standards: At least C– in each course in the minor. GPA ≥ 2.0 for all courses in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. Required courses:

    ENGRD 270 Basic Engineering Probability and Statistics

    OR&IE 360 Basic Engineering Probability and Statistics II *or* ECE 310 Introduction to Probability and Random Signals

2. Four of these (≥ 11 credits)*:

    OR&IE 361 Introductory Engineering Stochastic Processes I *or* ECE 411 Random Signals in Communications/Signal Processing

    OR&IE 476 Applied Linear Statistical Models

    OR&IE 576 Regression

    OR&IE 563 Applied Time Series Analysis

    OR&IE 575 Experimental Design

    OR&IE 577 Quality Control

    OR&IE 580 Monte Carlo Simulation Modeling

    OR&IE 581 Discrete-Event Simulation

    MATH 472 Basic Probability *or* BTRY 409 Theory of Statistics

    BTRY 602 Statistical Methods II

    BTRY 603 Statistical Methods III *or* ILRST 411 Statistical Analysis of Qualitative Data

    ILRST 310 Statistical Sampling

    ILRST 314 Graphical Methods for Data Analysis

    ILRST 410 Techniques of Multivariate Analysis

*Other course options approved by petition in advance. Some of these courses require others as prerequisites. All these courses are cross-listed under the Department of Statistical Science.

MINOR: ENVIRONMENTAL ENGINEERING

Offered jointly by the Department of Biological and Environmental Engineering and the School of Civil and Environmental Engineering

Contact: 207 Riley-Robb Hall, 255-2173, www.bee.cornell.edu, or 221 Hollister Hall, 255-3412, www.cee.cornell.edu

Students affiliated with all majors except environmental engineering are eligible to participate in this minor. Students majoring in biological engineering or civil engineering are eligible if they are not following the environmental concentration offered by those majors. Eligible civil engineering majors may not use courses simultaneously to satisfy a requirement for the minor and as a major-approved elective or design elective.

A fundamental challenge for the engineering profession is development of a sustainable society and environmentally responsible industry and agriculture reflecting an integration of economic and environmental objectives. We are called upon to be trustees and managers of our nation's resources, the air in our cities, and water in our aquifers, streams, estuaries, and coastal areas. This minor encourages engineering students to learn about the scientific, engineering, and economic foundations of environmental engineering so that they are better able to address environmental management issues.

Academic standards: At least C– in each course in the minor. GPA ≥ 2.0 for all courses in the minor.

Requirements

At least six courses (≥ 18 credits), chosen from the following groups, with at least one course from each group.

Group A. Environmental engineering processes:

BEE/ENGRD 251 Engineering for a Sustainable Society

CEE 351 Environmental Quality Engineering

CEE 451 Microbiology for Environmental Engineering

CEE 452 Water Supply Engineering

CEE 453 Laboratory Research in Environmental Engineering

CEE 454 Sustainable Small-Scale Water Supplies

CEE 455 AguaClara: Sustainable Water Supply Project

BEE 476 Solid Waste Engineering

BEE 478 Ecological Engineering

CEE 444 Environmental Site and Remediation Engineering

CEE 492 Engineers for a Sustainable World

BEE 651 Bioremediation

CEE 653 Water Chemistry for Environmental Engineering

CEE 656 Physical/Chemical Process

CEE 657 Biological Processes

CEE 658 Biodegradation and Biocatalysis

Group B. Environmental systems

ENGRI/CEE 113* Sustainability Design for Appledore Island (*may count only if taken before the junior year)

BEE 475 Environmental Systems Analysis

CEE 597 Risk Analysis and Management

CEE 623 Environmental Quality Systems Engineering

Group C. Hydraulics, hydrology, and environmental fluid mechanics

CEE 331 Fluid Mechanics (CHEME 323 or M&AE 323 may be substituted for CEE 331)

CEE 332 Hydraulic Engineering

BEE 371 Physical Hydrology for Ecosystems

BEE 471 Introduction to Groundwater

CEE 432 Hydrology

CEE 436 Case Studies in Environmental Fluid Mechanics

CEE 437 Experimental Methods in Fluid Dynamics

BEE 473 Watershed Engineering

BEE 474 Water and Landscape Engineering Applications

CEE 631 Computational Simulation of Transport in the Environment

CEE 633 Flow in Porous Media and Groundwater

CEE 655 Transport, Mixing, and Transformation in the Environment

BEE 671 Analysis of the Flow of Water and Chemicals in Soils

BEE 672 Drainage

MINOR: GAME DESIGN

Offered by the Department of Computer Science

See: gdiac.cis.cornell.edu/courses.php

To complete the Game Design minor, the student must take at least six (6) courses (18-credit minimum) chosen as follows:

Required Courses: Complete the following two courses:

- CIS 300 Digital Game Design
- CIS 400 Advanced Projects in Game Design

Additional Courses: Choose four of the following courses:

- INFO 200 Introduction to Game Design Theory (pending approval)
- CS 211 Object-oriented Programming and Data Structures
- PSYCH 342 Human Perception: Graphics, Art, and Visual Display
- INFO 345 Human-Computer Interaction Design
- CS 419 Computer Networks
- COMM 422 Psychology of Media and Beyond
- INFO 440 Advanced Human-Computer Interaction Design
- CS 465 Introduction to Computer Graphics
- CS 472 Foundations of Artificial Intelligence
- ECE 476 Digital Systems Design Using Microcontrollers
- CIS 565 Computer Animation
- CS 567 Physically Based Animation for Computer Graphics
- CS 569 Interactive Computer Graphics

Academic Standards:

- A letter grade of at least C is required for each course in the minor.
- CS students may not count CS courses toward the completion of this minor.

MINOR: SCIENCE OF EARTH SYSTEMS

Offered by the Department of Earth and Atmospheric Sciences

Contact: 2124 Snee Hall, 255-5466, www.eas.cornell.edu

Students affiliated with all majors except science of earth systems are eligible to participate.

Some of the major problems facing mankind in this century involve earth science, especially the generation of new energy sources for a growing world population, and engineers will be challenged to solve these problems. This minor will prepare engineering students to understand the natural operating systems of Earth and the tools and techniques used by earth scientists to understand and monitor these solid and fluid systems.

Academic standards: At least C– in each course in the minor. GPA ≥ 2.0 for all courses in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. EAS 220 The Earth System
2. At least two of these courses:

   EAS 301 Evolution of the Earth System

   EAS 303 Introduction to Biogeochemistry

   EAS 304 Interior of the Earth

   EAS 305 Climate Dynamics
3. Additional EAS courses at the 300 level or higher. These may include, e.g., additional courses from the above lists, undergraduate research courses, and outdoor field courses.

MINOR: INDUSTRIAL SYSTEMS AND INFORMATION TECHNOLOGY

Offered by the School of Operations and Information Engineering

Contact: 203 Rhodes Hall, 255-5088, www.orie.cornell.edu

Students affiliated with all majors except Operations Research and Engineering and Information Science, Systems, and Technology are eligible to participate in this minor.

The aim of this minor is to provide an in-depth education in the issues involved in the design and analysis of industrial systems, and the tools from information technology that have become an integral part of the manufacturing process. Students will become familiar with the problems, perspectives, and methods of modern industrial engineering and be prepared to work with industrial engineers in designing and managing manufacturing and service operations. That is, rather than providing a comprehensive view of the range of methodological foundations of operations research, this minor is designed to give the student a focused education in the application area most closely associated with these techniques.

Academic standards: At least C– in each course in the minor. GPA ≥ 2.0 for all courses in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. At least three of the following:

   ENGRD 270 Basic Engineering Probability and Statistics

   OR&IE 312 Industrial Data and Systems Analysis

   OR&IE 320 Optimization I

   OR&IE 480 Information Technology
2. The remaining courses chosen from:

   OR&IE 350 Financial and Managerial Accounting

   OR&IE 416 Design of Manufacturing Systems

   OR&IE 451 Economic Analysis of Engineering Systems

   OR&IE 525 Production Planning and Scheduling Theory and Practice

   OR&IE 577 Quality Control

   OR&IE 580 Monte Carlo Simulation

   OR&IE 581 Discrete-Event Simulation

MINOR: INFORMATION SCIENCE

Offered by the Department of Computer Science

Contact: Undergraduate Programs Office, 303 Upson Hall, 255-9837, www.infosci.cornell.edu

Students affiliated with any major except Information Science, Systems, and Technology are eligible to participate in this minor.

The interdisciplinary field of information science covers all aspects of digital information. The program has three main areas: information systems, human-centered systems, and social systems. Information systems studies the computer science problems of representing, storing, manipulating, and using digital information. Human-centered systems studies the relationship between humans and information, drawing from human-computer interaction and cognitive science. Social systems examines information in its economic, legal, political, cultural, and social contexts.

The minor has been designed to ensure that students have substantial grounding in all three areas in addition to having a working knowledge of basic probability and statistics necessary for analyzing real-world data.

Academic standards: At least C in all courses for the minor; S-U courses are not allowed.

Requirements

Note: These requirements apply to students in the College of Engineering. Students who are not in the College of Engineering should refer to the IS minor requirements listed in the CIS section of this publication.

At least six courses (18 credits) chosen as follows:

- Statistics: one course (must be ENGRD 270 or CEE 304)
- Information systems (primarily computer science): two courses
- Human-centered systems (human computer interaction and cognitive science): one course
- Social systems (social, economic, political, cultural, and legal issues): one course
- Elective: one additional course from either human-centered systems or social systems

Statistics

An introductory course that provides a working knowledge of basic probability and statistics and their application to analyzing real-world data.

ENGRD 270 Basic Engineering Probability and Statistics

CEE 304 Uncertainty Analysis in Engineering

Information Systems

INFO 172 Computation, Information, and Intelligence

CS 211 Object-oriented Programming and Data Structures*

INFO 230 Intermediate Design and Programming for the Web*

CIS 300 Introduction to Computer Game Design

INFO 330 Data-Driven Web Applications

LING 424 Computational Linguistics

INFO 430 Information Retrieval

INFO 431 Web Information Systems

CS 432 Introduction to Database Systems

CS 465 Introduction to Computer Graphics

CS 472 Foundations of Artificial Intelligence

LING 474 Introduction to Natural Language Processing

OR&IE 474 Statistical Data Mining I

CS 478 Machine Learning

OR&IE 480 Information Technology

OR&IE 481 Delivering OR Solutions with Information Technology

OR&IE 483 Applications of Operations Research and Game Theory to Information Technology

CS 501 Software Engineering

CS 513 System Security

CS 530 Architecture of Large-Scale Information Systems

ECE 562 Fundamental Information Theory

CS 578 Empirical Methods in Machine Learning and Data Mining

*Computer Science majors may not use INFO 230. CS 211 cannot be used by majors for which it is a required course, e.g., Computer Science (CS) and Operations Research and Information Engineering OR&IE).

Human-centered systems

COGST 101 Introduction to Cognitive Science

PSYCH 205 Perception

INFO 214 Cognitive Psychology

INFO 245 Psychology of Social Computing

PSYCH 280 Introduction to Social Psychology

PSYCH 342 Human Perception: Applications to Computer Graphics, Art, and Visual Display

INFO 345 Human–Computer Interaction Design

PSYCH 347 Psychology of Visual Communications

PSYCH 380 Social Cognition

PSYCH 413 Information Processing: Conscious and Unconscious

PSYCH 416 Modeling Perception and Cognition

INFO 440 Advanced Human-Computer Interaction Design

INFO 445 Seminar in Computer-Mediated Communication

INFO 450 Language and Technology

DEA 470 Applied Ergonomic Methods

Social systems

INFO 204 Networks

S&TS 250 Technology in Society

INFO 292 Inventing an Information Society

ECON 301 Microeconomics*

SOC 304 Social Networks and Social Processes

ECON 313 Intermediate Microeconomic Theory*

INFO 320 New Media and Society

AEM 322 Technology, Information, and Business Strategy*

INFO 349 Media Technologies

INFO 355 Computers: From the 17th Century to the Dot.com Boom

INFO 356 Computing Cultures

INFO 366 History and Theory of Digital Art

ECON 368 Game Theory*

INFO 387 The Automatic Lifestyle: Consumer Culture and Technology

S&TS 411 Knowledge, Technology, and Property

INFO 415 Environmental Interventions

ECON 419 Economic Decisions Under Uncertainty

COMM 428 Communication Law

INFO 429 Copyright in the Digital Age

OR&IE 435 Introduction to Game Theory*

INFO 444 Responsive Environments

S&TS 438 Minds, Machines, and Intelligence

INFO 447 Social and Economic Data

H ADM 474 Strategic Information Systems*

ECON 476/477 Decision Theory I and II

H ADM 489 The Law of the Internet and E-Commerce

INFO 515 Culture, Law, and Politics of the Internet

*Only one of ECON 301 and 313 may be taken for IS credit. Only one of OR&IE 435 and ECON 368 may be taken for IS credit. Only one of AEM 322 and H ADM 474 may be taken for IS credit.

MINOR: MATERIALS SCIENCE AND ENGINEERING

Offered by the Department of Materials Science and Engineering

Contact: 214 Bard Hall, 255-9159, www.mse.cornell.edu

Students affiliated with all majors except materials science and engineering are eligible to participate in this minor.

Materials properties are the foundation of many engineering disciplines including mechanical, civil, chemical, and electrical engineering. This minor provides engineers in related areas with a fundamental understanding of mechanisms that determine the ultimate performance, properties, and processing characteristics of modern materials.

Academic standards: At least C in each course in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. ENGRD 261 Mechanical Properties of Materials: From Nanodevices to Superstructures, or ENGRD 262 Electronic Materials for the Information Age
2. Two of:

   MS&E 206 Atomic and Molecular Structure of Matter

   MS&E 301 Materials Chemistry

   MS&E 303 Thermodynamics of Condensed Systems

   MS&E 304 Kinetics, Diffusion, and Phase Transformations

   MS&E 305 Electronic, Magnetic, and Dielectric Properties of Materials

   MS&E 402 Mechanical Properties of Materials, Processing, and Design
3. Three electives chosen from:

   Any MS&E course at the 300 level or above.

Selected courses in materials properties and processing (at the 300 level or above) from A&EP, CHEME, CEE, ECE, M&AE, PHYS, and CHEM, as approved by the MS&E undergraduate major coordinator.

MINOR: MECHANICAL ENGINEERING

Offered by the Sibley School of Mechanical and Aerospace Engineering

Contact: 108 Upson Hall, 255-3573, www.mae.cornell.edu

Students affiliated with A&EP, BEE, CEE, CHEME, CS, EAS, ECE, ENVE, ISST, MS&E, and OR&IE are eligible to participate in this minor. Students intending to earn a minor in mechanical engineering should seek advice and pre-approval of their minor academic program from the associate director for undergraduate affairs in mechanical engineering before taking courses toward the minor.

Academic standards: At least C– in each course in the minor.

Requirements

At least six courses (≥ 18 credits) from among the following: M&AE courses at the 200 level or above; ENGRD 202 Mechanics of Solids; ENGRD 203 Dynamics.

Rules for selecting courses:

1. The selection of courses must satisfy the following three requirements.
   a. At least two courses must be numbered above 300.
   b. At least one course must be either (i) numbered above 500 or (ii) numbered

above 326 and have as a prerequisite ENGRD 202, 203, or a M&AE course.

c. Each course must be worth at least 3 credits.

2. All courses used to satisfy the M&AE minor must be M&AE courses, ENGRD 202 or 203. No substitutions will be accepted from other departments at Cornell or elsewhere. Transfer credit may not be used to satisfy the M&AE minor. M&AE 111 Naval Ship Systems, or M&AE 498 Teaching Experience in Mechanical Engineering, may not be used toward satisfying the M.E. minor.

MINOR: OPERATIONS RESEARCH AND MANAGEMENT SCIENCE

Offered by the School of Operations Research and Information Engineering

Contact: 203 Rhodes Hall, 255-5088, www.orie.cornell.edu

Students affiliated with all majors except Operations Research and Engineering and Information Science, Systems, and Technology are eligible to participate in this minor.

Operations research and management science aims to provide rational bases for decision making by seeking to understand and model complex situations and to use this understanding to predict system behavior and improve system performance. This minor gives the student the opportunity to obtain a wide exposure to the core methodological tools of the area, including mathematical programming, stochastic and statistical models, and simulation. The intent of this minor is to give a broad knowledge of these fundamentals, rather than to train the student in a particular application domain. With this preparation, students can adjust their advanced courses and pursue either methodological or application-oriented areas of greatest interest and relevance to the overall educational goals of their program.

Academic standards: At least C– in each course in the minor. GPA ≥ 2.0 for all courses in the minor.

Requirements

At least six courses (≥ 18 credits), chosen as follows:

1. At least three of these courses:

   ENGRD 270 Basic Engineering Probability and Statistics

   OR&IE 320 Optimization I

   OR&IE 321 Optimization II

   OR&IE 360 Engineering Probability and Statistics II

   OR&IE 361 Introduction to Engineering Stochastic Processes I

   OR&IE 580 Monte Carlo Simulation

   OR&IE 581 Discrete-Event Simulation

2. Any OR&IE courses at the 300 level or higher (including those in 1).

MASTER OF ENGINEERING DEGREES

Office of Research and Graduate Studies, and Professional Education (RGS), 222 Carpenter Hall, www.engineering.cornell.edu/student-services/orgspe/index.cfm.

The following one-year (30-credit) professional master of engineering (M.Eng.) degrees are offered (giving also the administering unit)

M.Eng. (Aerospace): mechanical and aerospace engineering

M.Eng. (Biological and Environmental): biological and environmental engineering

M.Eng. (Biomedical): biomedical engineering

M.Eng. (Chemical): chemical and biomolecular engineering

M.Eng. (Civil and Environmental): civil and environmental engineering

M.Eng. (Computer Science): computer science

M.Eng. (Electrical): electrical and computer engineering

M.Eng. (Engineering Mechanics): theoretical and applied mechanics

M.Eng. (Engineering Physics): applied and engineering physics

M.Eng. (Geological Sciences): earth and atmospheric sciences

M.Eng. (Materials): materials science and engineering

M.Eng. (Mechanical): mechanical and aerospace engineering

M.Eng. (OR&IE): operations research and information engineering

M.Eng. (Systems): systems engineering

These degrees are discussed below because the curricula are integrated with the undergraduate majors.

Many Cornell baccalaureate engineering graduates spend a fifth year at Cornell, earning an M.Eng. degree, although the program is also open to qualified graduates of other schools.

Requirements for admission vary by program. In general, the standard M.Eng. application requirements include:

- Statement of purpose
- Complete transcripts from each college or university attended
- At least two letters of recommendation
- Graduate Record Examination (GRE) scores—may not be required by all M.Eng. programs

Many M.Eng. programs waive the GRE requirement and one of the letters of recommendation for students with Cornell Engineering B.S. degrees. Check with the appropriate office for specific program requirements. A list of links and general admission information is posted on www.engr.cornell.edu/grad.

Superior Cornell students who will have between 1 and 8 credits remaining in their last undergraduate semester may petition for early admission to the M.Eng. program. They spend the last semester in both programs, finishing up their B.S. degree and also doing their first semester of the M.Eng. program.

Master of Engineering Minors and Concentrations

The following M.Eng. options are offered:

Minors

- bioengineering
- financial engineering
- manufacturing
- engineering management
- systems engineering

Concentrations

- information technology
- financial engineering
- applied operations research
- data mining and analytical marketing
- semester in strategic operations

A table indicates which minors and concentrations are available to students and contains detailed descriptions: www.engineering.cornell.edu/student-services.orgspe/upload/MEC_Minors_Concentration_Grid.pdf.

Cooperative Program with the Johnson Graduate School of Management

Undergraduates may be interested in a cooperative program at Cornell that leads to both master of engineering and master of business administration (M.B.A.) degrees. With appropriate curriculum planning, such a combined B.S./M.Eng./M.B.A. program can be completed in six years at Cornell, with time out for work experience. For undergraduates from other schools, it may be feasible to complete the M.Eng./M.B.A. program in two years, possibly with an intervening summer or time out for work experience if they do not already have it on coming to Cornell. This accelerated program often incorporates the 12-month M.B.A. program of the Johnson Graduate School of Management (JGSM).

Because 95 percent of the students in the JGSM have work experience, there will typically be a gap for work experience between the M.Eng. and M.B.A. portions of the program for students who do not already have it when beginning the M.Eng. portion.

For further details, visit Engineering Advising (167 Olin Hall), the M.Eng. office (222 Carpenter Hall), the JGSM office in Sage Hall, or the office of your intended undergraduate major.

Lester Knight Scholarship Program

The Lester Knight Scholarship Program is designed to assist and encourage Cornell Engineering students and alumni interested in combining their engineering education with a business degree. The program offers two options or categories of financial support:

- Undergraduate Knight Scholarship
- Alumni Knight Scholarship

Each program has different qualifications and is open to Cornell engineering students and alumni at different stages of their educational or professional career. Participation in the program requires admission by each respective academic program (M.Eng, M.B.A.) as well as an application to participate in the Knight Scholarship Program.

Contact RGS or refer to the Knight Scholarship web site (www.engr.cornell.edu/grad/knightscholarships) for program specifics.

MASTER OF ENGINEERING (AEROSPACE)

Offered by the Sibley School of Mechanical and Aerospace Engineering

Contact: 107 Upson Hall, 255-5250, www.mae.cornell.edu

The M.Eng. (Aerospace) degree program provides a one-year course of study for those who wish to develop a high level of competence in engineering science, current technology, and engineering design.

The program is designed to be flexible so that candidates may concentrate on any of a variety of specialty areas. These include aerodynamics, acoustics and noise, turbulent flows, nonequilibrium flows, combustion, dynamics and control, and computational fluid dynamics.

A coordinated program of courses for the entire year is agreed upon by the student and the faculty advisor. This program and any subsequent changes must also be approved by the chair of the M&AE Master of Engineering committee. An individual student's curriculum includes a 4- to 8-credit design course, a minimum of 12 credits in aerospace engineering or a closely related field, and sufficient technical electives to meet the total degree requirement of 30 credits (of which at least 28 credits must have letter grades).

Design projects must have an aerospace engineering design focus and have the close supervision of a faculty member. The projects may arise from individual faculty and student interests or from collaboration with industry.

All courses must be of true graduate nature. In general, all courses must be beyond the level of those required in an undergraduate engineering program; credit may be granted for an upper-level undergraduate course if the student has done little or no previous work in that subject area, but such courses must have the approval of the M&AE master of engineering chair.

Check with the M&AE graduate field office (107 Upson Hall) for additional degree requirements.

Students enrolled in the M.Eng. (Aerospace) degree program may take courses that also satisfy the requirements of the bioengineering, engineering management, or systems engineering minors.

MASTER OF ENGINEERING (AGRICULTURAL AND BIOLOGICAL)

Offered by the Department of Biological and Environmental Engineering

Contact: 207 Riley-Robb Hall, 255-2173, www.bee.cornell.edu

This degree is intended primarily for students who plan to enter engineering practice. The program is planned as an extension of an undergraduate major in biological and environmental engineering but can accommodate graduates of other engineering disciplines. The required 30 credits of courses are intended to strengthen the students' fundamental knowledge of engineering and develop their design skills. Of the 30 credits, 3 to 9 are earned for an engineering design project that culminates in a written and oral report.

Students may concentrate in one of the following areas: biological engineering, energy, environmental engineering, environmental management, food processing engineering, international agriculture, local roads, machine systems, soil and water engineering, and structures and environment. Elective courses are chosen from among engineering subject areas relevant to the student's interests and design project. Courses in technical communication, math, biology, and the physical sciences may also be taken as part of a coherent program. Students can qualify for the Dean's Certificate in energy, manufacturing, or bioengineering by choosing their design project and a number of electives from the designated topic areas.

MASTER OF ENGINEERING (BIOMEDICAL)

Offered by the Department of Biomedical Engineering

Contact: 361 Olin Hall, 255-2573, www.bme.cornell.edu

Our mechanistic understanding of biology has increased rapidly over the past 20 years, and many expect biology to drive engineering and technology in the next 50 years in much the same way that physics drove them in the 20th century. As biology has become more mechanistic, the opportunities to apply engineering approaches have increased enormously. Simultaneously, humanitarian needs and economic opportunities for the application of engineering to improve health care have increased significantly. Engineers who understand biology and can apply their knowledge and skills to improve human health are increasingly in demand. A professional degree in BME will prepare students to fill this increasing critical need.

The breadth and depth of knowledge needed in biomedical engineering makes a four-year B.S. degree program impractical. By combining the M.Eng. in BME with a strong B.S. program, a student can obtain the knowledge and skills necessary to be an effective professional biomedical engineer.

Students will acquire an in-depth knowledge of an essential area of biomedical engineering as well as a broad perspective of the biomedical engineering discipline that complements their undergraduate education in engineering or science. Graduates will be equipped to design biomedical devices and develop therapeutic strategies within the bounds of health care economics, the needs of patients and physicians, the regulatory environment for medical devices and pharmaceuticals, and stringent ethical standards.

Students will acquire depth by extending undergraduate concentrations, by selecting one of three areas for concentrated study, and by completing a design project in their area of concentration. The areas are biomedical mechanics and materials; bioinstrumentation/diagnostics; and drug delivery and cellular/tissue engineering. Design projects will be carried out in teams to take advantage of the diversity of student backgrounds and, when possible, projects will be done in collaboration with industrial or clinical partners.

Students from a wide variety of backgrounds in engineering and science are encouraged to apply. They are expected to have completed two semesters of calculus-based physics, at least three semesters of math, starting with calculus, and introductory computer science.

A knowledge of molecular- and cellular-base biomedical engineering and engineering analysis of physiological systems at the level of BME 301, 302, 401, and 402 is highly recommended. This knowledge can be demonstrated through appropriate undergraduate course work (at least C in each class). Students lacking the appropriate background may need to complete additional courses (beyond the normal 30 credits) to demonstrate appropriate knowledge in these two subject areas.

MASTER OF ENGINEERING (CHEMICAL)

Offered by the School of Chemical and Biomolecular Engineering

Contact: 358 Olin Hall, 255-4550, www.cheme.cornell.edu

This degree is awarded at the end of one year of graduate study with successful completion of 30 credits of required and elective courses in technical fields including engineering, math, chemistry, physics, and business administration. Some courses emphasize design and optimization based on the economic factors that affect design alternatives for processes, equipment, and plants. General admission and degree requirements are described at the beginning of the section "Master of Engineering Degrees."

Specific requirements include

1. 12 credits in CHEME courses distributed among chemical and biomolecular engineering fundamentals. One required from among CHEME 711, 731, and 751 and the remainder in chemical and biomolecular engineering applications (partial list: CHEME 480, 481, 484, 520, 543, 572, 631, 640, and 661).
2. A minimum of 3 credits of an individual or group project, CHEME 565.
3. Knowledge of business practices and techniques for pollution abatement and control. This knowledge may have already been acquired by students as undergraduates. If not, then CHEME courses (e.g., CHEME 572 and 661) or other courses covering these topics are required.

MASTER OF ENGINEERING (CIVIL AND ENVIRONMENTAL)

Offered by the School of Civil and Environmental Engineering

Contact: 219 Hollister Hall, 255-7560, www.cee.cornell.edu

The Master of Engineering degree is a course work and project-oriented program. It is normally completed in two semesters of intensive study. Thirty credit hours are required, consisting of course work in a major concentration and a supporting area, as well as a design project.

Students may focus their studies in one of seven major subject areas: civil infrastructure systems, environmental and water resource systems engineering, environmental fluid mechanics and hydrology, environmental engineering, geotechnical engineering, structural engineering, and transportation systems engineering. Courses in supporting areas come from many disciplines, including architecture, computer science, economics, engineering management, historic preservation, materials science, microbiology and operations research to name just a few.

MASTER OF ENGINEERING (COMPUTER SCIENCE)

Offered by the Department of Computer Science

Contact: 4126 Upson Hall, 255-8593, www.cs.cornell.edu/grad/meng

The M.Eng. program in computer science can be started in either the fall or spring semester. This program is designed to develop expertise in system design and implementation in many areas of computer science, including computer networks, Internet architecture, fault-tolerant and secure systems, distributed and parallel computing, high-performance computer architecture, databases and data mining, multimedia systems, computer vision, computational tools for finance, computational biology (including genomics), software engineering, programming environments, and artificial intelligence.

A typical program includes several upper-division and graduate courses and a faculty-supervised project. The flexible requirements allow students to build up a program that closely matches their interests. In fact, slightly under half the courses may be taken outside the computer science department (many students choose to take several business administration courses). Project work, which may be done individually or in a small group, can often be associated with ongoing research in the Department of Computer Science in one of the areas listed above.

Cornell seniors may use the early admission option to effectively co-register for the M.Eng. program while completing the undergraduate degree. This option can be started in either the fall or spring semester. It applies to students who have 1 to 8 credits remaining to complete their undergraduate program. All remaining undergraduate degree requirements must be satisfied by the end of the first semester the student is enrolled in the M.Eng. "early admit" program.

Undergraduates majoring in computer science may be interested in a program that can lead, in the course of six years, to B.S., M.Eng. (computer science), and M.B.A. degrees. See "Master of Engineering Degrees."

MASTER OF ENGINEERING (ELECTRICAL)

Offered by the School of Electrical and Computer Engineering

Contact: Student Services Office, 223 Phillips Hall, 255-8414, www.ece.cornell.edu/aca-meng.cfm

The M.Eng. (Electrical) degree program prepares students either for professional work in Electrical and Computer Engineering and closely related areas or for further graduate study in a doctoral program. The M.Eng. degree differs from the master of science degree mainly in its emphasis on professional skills, engineering design, and analysis skills rather than basic research.

The program requires 30 credits of advanced technical course work beyond that expected in a typical undergraduate program, including at least four graduate-level courses in Electrical and Computer Engineering. The required Electrical and Computer Engineering design project may account for 3 to 8 credits of the M.Eng. program. Occasionally, students take part in very extensive projects and may petition to increase the project component to 10 credits. Students with special career goals, such as engineering management, may apply to use up to 11 credits of approved courses that have significant technical content but are taught in disciplines other than engineering, math, or the physical sciences.

Although admission to the M.Eng. (Electrical) program is highly competitive, all well-qualified students are urged to apply. Further information is available at the web site listed above.

MASTER OF ENGINEERING (ENGINEERING MANAGEMENT)

The M.Eng. program in Engineering Management is designed for engineers who want to stay in a technical environment but advance to managerial roles. Students learn to identify problems, formulate and analyze models to understand these problems, and interpret the results of analyses for managerial action.

A student's program of study is designed individually in consultation with an academic advisor and then submitted to the school's Professional Degree Committee for approval.

For the M.Eng. program in Engineering Management, the requirements are:

1. Three core courses: These include: CEE 590 Project Management, CEE 593 Engineering Management Methods, and CEE 591 Management Project.
2. Two focus courses, from a list that includes CEE 594, CEE 596, CEE 597, CEE 598, and CEE 690.
3. Two managerial breadth courses, including one in finance/accounting and one focused on behavior.
4. Three disciplinary or functional electives.

The School of Civil and Environmental Engineering cooperates with the Johnson Graduate School of Management in a joint program leading to both Master of Engineering and Master of Business Administration degrees. See the beginning of the section "Master of Engineering Degrees."

MASTER OF ENGINEERING (ENGINEERING MECHANICS)

Offered by the Department of Theoretical and Applied Mechanics

Contact: 212 Kimball Hall, 255-0988, www.tam.cornell.edu/meng1.html

This two-semester professional degree program stresses applications of Engineering Mechanics and Applied Mathematics and Modeling. The centerpiece of the program is a project, either single or team-based, on important real-world problems.

Engineering Mechanics: Students in this program will deepen and broaden their knowledge of mechanics as applied to different material systems. The course work centers on additional study of solid mechanics, fracture mechanics, materials and computational methods widely used in industries such as the finite element method. Potential employers are companies interested in computer modeling of mechanical systems and failure and reliability analysis.

Applied Mathematics and Modeling: Students in this program do course work in mathematical modeling and computational methods. They will have great flexibility in their choice of studies. Students who graduate from this program are in a good position to pursue higher degrees or work for financial or informational organizations.

Laboratories: T&AM has many laboratories related to research areas and courses of study for the M.Eng. program:

- Ultrasonic and Materials Characterization Laboratory—*Wolfgang Sachse*
- Bio-robotics and Locomotion Laboratory—*Andy Ruina*
- Granular Flow Research Laboratory—*Jim Jenkins*
- Composites Laboratory—*Leigh Phoenix and Petru Petrina*
- Fracture Mechanics Laboratory—*Alan Zehnder*
- Dynamics Laboratory—*Dan Mittler*
- Mechanics of Solids Laboratory—*Dan Mittler*
- Biological Fluid Dynamics Laboratory—*Jane Wang*

Course Work:

(project 10–12 credit hours)

Current Interesting Projects

1. Animal, Human and Robotic Locomotion—*Andy Ruina*
2. Dynamical Systems—*Richard Rand*
3. Stress Rupture Testing of High-Performance Fibers and Yarns—*S. Leigh Phoenix*
4. Mathematics of Finance (capital budgeting, economic analysis Scholes—Black Diffusion Theory)—*K. Bingham Cady*
5. Fracture and Reliability—*Hui, Phoenix, Zehnder*

6. Response Theory—*K. Bingham Cady*
7. Nuclear Reactor Theory—*K. Bingham Cady*
8. Determination of Elastic Constance of Composite Materials Using Ultrasonics—*Wolfgang Sachse*

Engineering Mechanics

Fall semester

Course	*Title*	*Credits*
T&AM 663	Solid Mechanics I	4
T&AM 570	Intermediate Dynamics	3
or		
T&AM 610	Methods of Applied Mathematics I	3
T&AM 800	Seminar	1

Spring semester

CEE 786	Fracture Mechanics	3
or		
T&AM 713	Fracture	3
T&AM 655	Composite Materials	4
MS&E 582	Mechanical Properties of Material, Processing and Design	4
M&AE 570	Finite Element Analyses for Mechanical and Aerospace Design	4
T&AM 800	Seminar	1

Applied Mathematics and Modeling

Fall semester

T&AM 610	Methods of Applied Mathematics I	3
T&AM 570	Intermediate Dynamics	3
CEE 771	Stochastic Mechanics in Science and Engineering	3
T&AM 800	Seminar	1

Spring semester

T&AM 611	Methods of Applied Mathematics II	3
T&AM 578	Nonlinear Dynamics and Chaos	3
T&AM 671	Hamiltonian Dynamics	3
or		
T&AM 674	Nonlinear Vibrations	3
M&AE 570	Finite Element Analyses for Mechanical and Aerospace Design	4
or		
CEE 672	Finite Element Analysis of Solids and Structures	3
T&AM 800	Seminar	1

MASTER OF ENGINEERING (ENGINEERING PHYSICS)

Offered by the School of Applied and Engineering Physics

Contact: 212 Clark Hall, 255-5198, www.aep.cornell.edu

The M.Eng. (Engineering Physics) degree may lead directly to employment in engineering design and development or may be a basis for further graduate work. Students have the opportunity to broaden and deepen their preparation in the general field of applied physics, or they may choose the more specific option of preparing for professional engineering work in a particular area such as laser and optical technology, nanostructure science and technology, device physics, materials characterization, or software engineering. Wide latitude is allowed in the choice of the required design project.

Students plan their program in consultation with the program chair. The objective is to provide a combination of a good general background in physics and introductory study in a specific field of applied physics. Candidates may enter with an undergraduate preparation in physics, engineering physics, or engineering. Those who have majored in physics usually seek advanced work with an emphasis on engineering; those who have majored in an engineering discipline generally seek to strengthen their physics base. Candidates coming from industry usually want instruction in both areas. Students granted the degree will have demonstrated competence in an appropriate core of basic physics. If this has not been accomplished before entering the M.Eng. program, undergraduate classes in electricity and magnetism, classical mechanics, and quantum mechanics may be required in addition to the classes taken to satisfy the M.Eng. requirements.

The degree requires 30 credits of graduate-level courses or their equivalent, with at least C– in each course, and distributed as follows:

1. a design project in applied science or engineering with a written final report (6 to 12 credits)
2. an integrated program of graduate-level courses, as discussed below (17 to 23 credits)
3. a required special-topics seminar course (1 credit)

The design project, which is proposed by the student and approved by the program chair, is carried out on an individual basis under the guidance of a member of the university faculty. It may be experimental or theoretical in nature; if it is not experimental, a laboratory physics course is required.

The individual program of study consists of a compatible sequence of courses focused on a specific area of applied physics or engineering. Its purpose is to provide an appropriate combination of physics and physics-related courses (applied math, statistical mechanics, applied quantum mechanics) and engineering electives (e.g., courses in biophysics, chemical engineering, electrical engineering, materials science, computer science, mechanical engineering, or nuclear engineering). Additional science and engineering electives may be included. Some courses at the senior level (400) are acceptable for credit toward the degree; other undergraduate courses may be required as prerequisites but may not be credited toward the degree.

MASTER OF ENGINEERING (GEOLOGICAL SCIENCES)

Offered by the Department of Earth and Atmospheric Sciences

Contact: 2124 Snee Hall, 255-5466, www.eas.cornell.edu

The one-year M.Eng. (Geological Sciences) degree program provides future professional geologists or engineers with the geological and engineering background they will need to analyze and solve engineering problems that involve geological variables and concepts. Individual programs are developed within two established options: geohydrology and environmental geophysics.

Incoming students are expected to have a strong background in mathematics, the physical sciences, and chemistry and have a strong interest and substantial background in the geological sciences. The 30-hour M.Eng. program is intended to extend and broaden this background to develop competence in four subject categories. Typical categories for the geohydrology option are porous media flow, geology, geochemistry, and numerical modeling. Typical categories for the environmental geophysics option are geophysics, geology, porous media fluid flow, and computer methods. The courses a student selects in a category will vary depending on the student's background. No courses may be required in some categories, and the categories can be adjusted to the student's interest and needs. Alternatives to numerical modeling in the geohydrology option could be economics or biochemistry, for example. To count toward the 30-credit degree requirement, courses must be at a graduate or advanced undergraduate level.

At least 10 of the 30 hours in the program must involve engineering design. Much of this requirement is normally met through a design project, which can account for over a third of the program (12 of 30 credits) and must constitute at least 3 credits. The design project must involve a significant geological component and lead to concrete conclusions or recommendations of an engineering nature. The project topic can be drawn from a student's nonacademic work experience but carried out or further developed with advice from a Cornell faculty member with expertise in the project area selected by the student. A design project in geohydrology would normally involve groundwater flow and mass transport. A design project in environmental geophysics might involve implementation of a field survey using seismological, geoelectrical, or ground-penetrating radar methods to map subsurface stratigraphic or structural features that control groundwater flow or contamination at a site. Projects are presented both in written form and orally in a design seminar at the end of the year.

MASTER OF ENGINEERING (MATERIALS SCIENCE AND ENGINEERING)

Offered by the Department of Materials Science and Engineering

Contact: 214 Bard Hall, 255-9159, www.mse.cornell.edu

Students who have completed a four-year undergraduate program in engineering or the physical sciences can be considered for admission into the M.Eng. (Materials) program. This 30-credit program includes course work and a master's design project. The project, which requires individual effort and initiative, is carried out under the supervision of a faculty member. Twelve credits are devoted to the project, which is normally experimental in nature, although computational or theoretical projects are also possible.

Courses for the additional 18 credits are selected from the graduate-level classes in materials science and engineering and from other related engineering fields approved by the faculty. Typically half of the courses are from MS&E. One 3-credit technical elective must include advanced math (modeling, computer application, or computer modeling) beyond the MS&E undergraduate requirements.

MASTER OF ENGINEERING (MECHANICAL)

Offered by the Sibley School of Mechanical and Aerospace Engineering

Contact: 107 Upson Hall, 255-5250, www.mae.cornell.edu

The M.Eng. (Mechanical) degree program provides a one-year course of study for those who wish to develop a high level of competence in engineering science, current technology, and engineering design.

Candidates may concentrate on any of a variety of specialty areas, including biomechanical engineering, combustion, propulsion and power systems, fluid mechanics, heat transfer, materials and manufacturing engineering, and mechanical systems and design.

A coordinated program of courses for the entire year is agreed upon by the student and the faculty advisor. This program and any subsequent changes must also be approved by the chair of the M&AE Master of Engineering committee. An individual student's curriculum includes a 4- to 8-credit design course, a minimum of 12 credits in mechanical engineering or a closely related field, and sufficient technical electives to meet the total degree requirement of 30 credits (of which at least 28 credits must have letter grades).

The design projects may arise from individual faculty and student interests or from collaboration with industry. All projects must have a mechanical engineering design focus and have the close supervision of a faculty member.

All courses must be of true graduate nature. In general, all courses must be beyond the level of those required in an undergraduate engineering program; credit may be granted for an upper-level undergraduate course if the student has done little or no previous work in that subject area, but such courses must have special approval of the M&AE master of engineering chair.

The technical electives may be courses of appropriate level in math, physics, chemistry, or engineering; a maximum of 3 credits may be taken in areas other than these if the courses are part of a well-defined program leading to specific professional objectives.

Check with the M&AE graduate field office (107 Upson Hall) for additional degree requirements.

Students enrolled in the M.Eng. (Mechanical) degree program may take courses that also satisfy the requirements of the bioengineering, engineering management, or systems manufacturing minors.

MASTER OF ENGINEERING (NUCLEAR)

Offered by the Nuclear Engineering Program

Contact: 312 Rhodes Hall, 255-1453, www.gradschool.cornell.edu/academics_research/fields/nucl-sci.html

The two-semester curriculum leading to the M.Eng. (Nuclear) degree is intended primarily for individuals who want a terminal professional degree, but it may also serve as preparation for doctoral study in nuclear science and engineering. The course of study covers the basic principles of nuclear reactor systems with a major emphasis on reactor safety and radiation protection and control.

The interdisciplinary nature of nuclear engineering allows students to enter from a variety of undergraduate concentrations. The recommended background is (1) an accredited baccalaureate degree in engineering, physics, or applied science; (2) physics, including atomic and nuclear physics; (3) math, including advanced calculus; and (4) thermodynamics. Students should see that they fulfill these requirements before beginning the program. In some cases, deficiencies in preparatory work may be made up by informal study during the preceding summer. General admission and degree requirements are described in the college's introductory section.

MASTER OF ENGINEERING (OPERATIONS RESEARCH AND INDUSTRIAL ENGINEERING)

Offered by the School of Operations Research and Information Engineering

Contact: 201 Rhodes Hall, 255-9128, www.orie.cornell.edu

This professional degree program stresses applications of operations research. The centerpiece of the program is a team-based project on a significant real-world problem. The course work centers on additional study of analytical techniques, with particular emphasis on engineering applications, especially in the design or improvement of systems and methods in manufacturing, information, finance, and nonprofit organizations.

General admission and degree requirements are described in the introductory "Degree Programs" section. The M.Eng. (OR&IE) program is intended for three groups of students: graduates of the undergraduate major in ORE who wish to expand their practical knowledge of the field; Cornell undergraduates in other math-based areas who want to broaden their exposure to OR&IE; and qualified non-Cornellians with strong backgrounds from other programs in the United States and abroad.

Undergraduates majoring in engineering may be interested in a program that can lead, in the course of six years, to B.S., M.Eng., and M.B.A. degrees. See "Master of Engineering Degrees."

Graduates with a technical background may be interested in the possibility of completing both an M.Eng. and an M.B.A. program within a period of two years, possibly with intervening work experience. These possibilities incorporate the Johnson Graduate School of Management (JGSM) "Accelerated MBA" (formerly Twelve-Month Option).

For admission, the entering student should have completed courses in probability and statistics and in computer science, as well as four semesters of mathematics, through differential equations, linear algebra, and multivariate calculus. For the financial engineering concentration the entering student must also have completed OR&IE 360/560 and a basic finance course.

Program requirements include a core of OR&IE courses plus technical electives chosen from a broad array of offerings. The choice of a particular elective sequence plus a specific project course results in completion of one of several concentrations and minors within the program. The concentrations include applied operations research, financial engineering, information technology, strategic operations (which incorporates the Semester in Strategic Operations at JGSM), and data mining and analytical marketing. Minors include systems engineering and manufacturing. These minors and the strategic operations concentration are offered jointly with various other Cornell departments and schools and they provide the opportunity to interact on projects and in class with specialists in other engineering fields and in business. Many students select the applied operations research option, offered only by OR&IE, which has project teams made up entirely of OR&IE M.Eng. students and offers the broadest choice of elective courses and career alternatives, in business and elsewhere. For information about the manufacturing minor, contact the Center for Manufacturing Enterprise, 291 Grumman Hall, 255-5545; about the Semester in Strategic Operations, 304 Sage Hall, 255-4691; about systems engineering, 280 Rhodes Hall, 254-8998, and for others, 201 Rhodes Hall, 255-9128. For students lacking an undergraduate degree in operations research equivalent to Cornell's, the financial engineering concentration, which is highly specialized, requires additional prerequisites and takes three semesters to complete. This permits an industry internship in the summer between semesters. For the other concentrations and minors, the typical study plans are as follows:

1. For matriculants with preparation comparable to that provided by the undergraduate major in operations research and engineering:

Fall semester	*Credits*
OR&IE 516 Case Studies	1
OR&IE 893 Applied OR&IE Colloquium	1
M.Eng. project	1
Technical electives	12

Spring semester	
OR&IE 894 Applied OR&IE Colloquium	1
M.Eng. project	minimum of 4
Technical electives	10

2. For matriculants from other majors who minimally fulfill the prerequisite requirements (students who have the equivalent of OR&IE 520, 523, and 560 will take other OR&IE electives in their place):

Fall semester	*Credits*
OR&IE 560 Engineering Probability and Statistics II	4
OR&IE 520 Optimization I	4
OR&IE 516 Case Studies	1
OR&IE 580 Monte Carlo Simulation	2
OR&IE 581 Discrete-Event Simulation	2
OR&IE 893 Applied OR&IE Colloquium	1
M.Eng. project	1

Spring semester	
OR&IE 522 Topics in Linear Optimization	1
OR&IE 523 Introduction to Stochastic Processes I	4
OR&IE 894 Applied OR&IE Colloquium	1
M.Eng. project	minimum of 4
Technical electives	5

For both of the above pro forma schedules, at least 12 credit hours of the specified electives must be chosen from the list of courses offered by the School of Operations Research and Information Engineering. For scheduling reasons, some concentrations and minors may entail an additional summer or semester, depending on the student's preparation.

The project requirement can be met in a variety of ways. Common elements in all project experiences include working as part of a group of three to five students on an engineering design problem, meeting with a faculty member on a regular basis, and oral and written presentation of the results obtained. Most projects address problems that actually exist in manufacturing firms, financial firms, and service organizations such as hospitals.

Additional program requirements are described in the *Master of Engineering Handbook* and on the web. For further details, see the contact information at the beginning of this section.

MASTER OF ENGINEERING (SYSTEMS ENGINEERING)

Offered by The Systems Engineering Program

Contact: 206 Rhodes Hall, 254-8998, www.systemseng.cornell.edu

Today's engineering environment is increasingly complex and rapidly changing. Due in part to emerging technologies and globalization, engineers must think in terms of complex, integrated, globally optimized solutions to devise designs that address the complexity of the real world. Success in this environment requires a comprehensive understanding of systems engineering.

The Systems Engineering Program emphasizes the fundamentals of requirements analysis, systems architecture, product development, project management, optimization, simulation, and systems analysis. The program's strength in these areas helps promote an understanding of the systems process throughout an organization and prepares students to transition from designing and managing independent engineering components and projects to creating integrated solutions that meet customer needs.

The M.Eng. (Systems Engineering) program is designed for students with a solid disciplinary background who want to specialize in Systems Engineering. It requires a minimum of 30 credit hours. Students must complete the following required courses:

Applied Systems Engineering (3 credits)

Systems Architecture, Behavior, and Optimization (3 credits)

Project Management (CEE 590) (4 credits)

Systems Engineering Design Project (6–8 credits)

Approved electives account for the remaining credits to reach the minimum of 30 credits required for the degree and are to be chosen from the following areas:

Systems Modeling and Analysis (at least one course)

Courses that enrich the understanding of generic methods to design and analyze systems including courses in simulation, feedback and control, decision-making, or risk analysis.

Systems Applications

Courses that provide depth in the design and operation of specific systems such as power, communication, software, manufacturing, or transportation.

Systems Management (at most one course):

Courses that enhance student understanding of the management activities and processes which are necessary to successfully design and operate systems.

In addition to the Master of Engineering degree in Systems Engineering, the Systems Engineering Program offers a second course of study: the minor in Systems Engineering. The SE minor is designed for students who want a concentration in Systems Engineering as part of the Master of Engineering degree in another engineering discipline.

ENGINEERING COURSES

Courses offered in the College of Engineering are listed under the various departments and schools.

Courses are identified with a standard abbreviation followed by a three-digit number.

Engineering Communications	ENGRC
Engineering Distribution	ENGRD
Engineering General Interest	ENGRG
Engineering Introductions	ENGRI
Biological and Environmental Engineering	BEE
Applied and Engineering Physics	A&EP
Chemical and Biomolecular Engineering	CHEME
Civil and Environmental Engineering	CEE
Computer Science	CS
Computing and Information Science	CIS
Earth and Atmospheric Sciences	EAS
Electrical and Computer Engineering	ECE
Information Science	INFO
Materials Science and Engineering	MS&E
Mechanical and Aerospace Engineering	M&AE
Nuclear Science and Engineering	NS&E
Operations Research and Information Engineering	OR&IE
Systems Engineering	SYSEN
Theoretical and Applied Mechanics	T&AM

ENGINEERING COMMON COURSES

Engineering Communications Courses

Courses in this category, offered by the Engineering Communications Program (ECP), develop writing and oral-presentation skills needed by engineers.

ENGRC 334(3340) Independent Study in Engineering Communications

1–3 credits, variable. Letter grades. TBA with instructor.

Members of the ECP occasionally give independent (also called "directed") studies in engineering communications, typically with students who are ready for advanced work in technical writing. A student doing a directed study works one-on-one with an ECP instructor to pursue an aspect of professional communications in more depth than is possible in the ECP's regular courses. Various types of projects are possible, e.g., studying forms of technical documentation, creating user manuals, analyzing and producing technical graphics, reading and writing about problems in engineering practice, and writing about technical topics for the public.

ENGRC 335(3350) Communications for Engineering Managers (LA)

Fall, spring. 3 credits. Fulfills college technical-writing requirement. May be used as free or approved elective in expressive arts. Intended for juniors and seniors. Limited to 20 students per sec. Prerequisite: two first-year writing seminars and major affiliation.

This seminar focuses on communications in organizational contexts common to engineering graduates. Topics may include internal and external communications; balancing visual and verbal elements in documents and oral presentations; teamwork and leadership; running and attending meetings; management strategies; and communicating with colleagues, superiors, subordinates, and clients. Students develop writing and management strategies that they apply in individual and team assignments. They learn how to organize technical and managerial information, articulate and support ideas, and communicate with technical and nontechnical audiences.

ENGRC 350(3500) Engineering Communications (LA)

Fall and spring. 3 credits. Designed for juniors and seniors. Fulfills college technical-writing requirement. May be used as free or approved elective in expressive arts. Limited to 20 students per sec.

Prerequisite: two first-year writing seminars and affiliation with a major.

This course prepares students for important communication activities. They write various types of documents (e.g., letters, memos, executive summaries, problem analyses, proposals, progress reports), give oral presentations, and incorporate graphics in their oral and written work. Students learn how to communicate specialized information to different audiences (e.g., technical and nontechnical people, colleagues and clients, peers and supervisors, in-house departments, and government agencies), work in teams, and address organizational and ethical issues. The course material is drawn from professional contexts, principally engineering, and it generates lively discussion. The class size ensures close attention to each student's work. (Note: Absences are limited to three, after which sharp penalties occur.)

Engineering Distribution Courses

Courses in this category are sophomore-level courses cross-listed with a department. These courses are intended to introduce students to more advanced concepts of engineering and may require pre- or corequisites.

ENGRD 202(2020) Mechanics of Solids (also T&AM 202[2020])

Fall, spring. 4 credits. Prerequisite: PHYS 112, co-registration in MATH 192, or permission of instructor. All students must take a lab section. Staff.

Covers principles of statics, force systems, and equilibrium; frames; mechanics of deformable solids, stress, strain, statically indeterminate problems; mechanical properties of engineering materials; axial force, shearing force, bending moment, thermal stress, stretching; bending and torsion of bars. Laboratory experiments demonstrate basic principles of solid mechanics.

ENGRD 203(2030) Dynamics (also T&AM 203[2030])

Fall, spring. 3 credits. Prerequisite: ENGRD/T&AM 202, co-registration in MATH 293, or permission of instructor. All students must take a lab and a section.

Newtonian dynamics of a particle, systems of particles, a rigid body. Kinematics, motion relative to a moving frame. Impulse, momentum, angular momentum, energy. Rigid-body kinematics, angular velocity, moment of momentum, the inertia tensor. Euler equations, the gyroscope. Laboratory experiments demonstrate basic principles of dynamics.

ENGRD 210(2100) Introduction to Circuits for Electrical and Computer Engineers (also ECE 210[2100])

Fall, spring. 4 credits. Corequisites: MATH 293 and PHYS 213. All students must take a lab and a section.

First course in electrical circuits and electronics that establishes the fundamental properties of circuits with application to modern electronics. Topics include circuit analysis methods, operational amplifiers, basic filter circuits, and elementary transistor principles. The laboratory experiments are coupled closely with the lectures.

ENGRD 211(2110) Object-Oriented Programming and Data Structures (also CS 211[2110])

Fall, spring, summer. 3 credits. Prerequisite: CS 100J, CS 101J, or CS 100H or CS 100M if completed before fall 2007, or equivalent course in Java or C++.

Intermediate programming in a high-level language and introduction to computer science. Topics include program structure and organization, object-oriented programming (classes, objects, types, sub-typing), graphical user interfaces, algorithm analysis (asymptotic complexity, big "O" notation), recursion, data structures (lists, trees, stacks, queues, heaps, search trees, hash tables, graphs), simple graph algorithms. Java is the principal programming language.

ENGRD 219(2190) Mass and Energy Balances (also CHEME 219[2190])

Fall. 3 credits. Corequisite: physical chemistry course or permission of instructor. S. Daniel.

Engineering problems involving material and energy balances. Batch and continuous reactive systems in the steady and unsteady states. Introduction to phase equilibria for multicomponent systems. Examples drawn from a variety of chemical and biomolecular processes.

ENGRD 221(2210) Thermodynamics (also M&AE 221[2210])

Fall, spring, may be offered summer. 3 credits. Prerequisites: MATH 192, Calculus for Engineers, and PHYS 112, Physics I, Mechanics. Staff.

Presents the definitions, concepts, and laws of thermodynamics. Topics considered include the first and second laws, thermodynamic property relationships, and applications to vapor and gas power systems, refrigeration, and heat pump systems. Examples and problems are related to contemporary aspects of energy and power generation and to broader environmental issues.

ENGRD 230(2300) Introduction to Digital Logic Design (also ECE 230[2300])

Fall, spring. 4 credits. Prerequisite: CS 100.

Introduction to the design and implementation of practical digital circuits. Topics include transistor network design, Boolean algebra, combinational circuits, sequential circuits, finite state machine design, and analog and digital converters. Design methodology using both discrete components and hardware description languages is covered in the weekly laboratory portion of the course.

ENGRD 251(2510) Engineering for a Sustainable Society (also BEE 251[2510])

Fall. 3 credits. Pre- or corequisite: MATH 293.

Case studies of contemporary environmental issues including pollutant distribution in natural systems, air quality, hazardous waste management, and sustainable development. Emphasis is on the application of mathematics, physics, and engineering sciences to solve energy and mass balances in environmental sciences. Students are introduced to the basic chemistry, ecology, biology, ethics, and environmental legislation relevant to the particular environmental problem. BEE students must complete either BEE 251 or BEE 260 according to their academic plan. BEE students who complete both BEE 251 and BEE 260 receive engineering credit for only one of these courses.

ENGRD 252(2520) The Physics of Life (also A&EP 252[2520])

Fall. 3 credits. Prerequisites: MATH 192, CHEM 207 or 211, and co-registration in or completion of PHYS 213. L. Pollack.

Introduces the physics of biological macromolecules (e.g., proteins, DNA, RNA) to students of the physical sciences or engineering who have little or no background in biology. The macromolecules are studied from three perspectives. First, the biological role or function of each class of macromolecules is considered. Second, a quantitative description of the physical interactions that determine the behavior of these systems is provided. Finally, techniques that are commonly used to probe these systems, with an emphasis on current research, are discussed.

ENGRD 260(2600) Principles of Biological Engineering (also BEE 260[2600])

Fall. 3 credits. Pre- or corequisite: MATH 293.

Focuses on the integration of biological systems with engineering, math, and physical principles. Students learn how to formulate equations for biological systems and practice it in homework sets. Topics range from molecular principles of reaction kinetics and molecular binding events to macroscopic applications, such as energy and mass balances of bioprocessing and engineering design of implantable sensors. BEE students must complete either BEE 251 or BEE 260 according to their academic plan. BEE students who complete both BEE 251 and BEE 260 receive engineering credit for only one of these courses.

ENGRD 261(2610) Mechanical Properties of Materials: From Nanodevices to Superstructures (also MS&E 261[2610])

Fall. 3 credits. S. Sass.

Examines the mechanical properties of materials (e.g., strength, stiffness, toughness, ductility) and their physical origins. The relationship of the elastic, plastic, and fracture behavior to microscopic structure in metals, ceramics, polymers, and composite materials is explored. Effects of time and temperature on materials properties are discussed. This course emphasizes considerations for design and optimal performance of materials and engineered objects.

ENGRD 262(2620) Electronic Materials for the Information Age (also MS&E 262[2620])

Spring. 3 credits. Prerequisite: MATH 192. Corequisite: PHYS 213 or permission of instructor. G. Malliaras.

Examines the electrical and optical properties of materials. Topics include the mechanism of electrical conduction in metals, semiconductors and insulators, the tuning of electrical properties in semiconductors, the transport of charge across metal/semiconductor and semiconductor/semiconductor junctions, and the interaction of materials with light. Applications in electrophotography, solar cells, electronics, and display technologies are discussed.

ENGRD 264(2640) Computer-Instrumentation Design (also A&EP 264[2640])

Fall, spring. 3 credits. Prerequisite: CS 100; permission of instructor for seniors. 1 lec, 1 lab. T. Cool.

Covers the use of a small computer in an engineering or scientific research lab. The experiments and devices investigated include: analog to digital converters (ADC), digital to analog converters (DAC), digital input/output (I/O), counter/timers, serial port communications, digital temperature control, error analysis, nonlinear least squares fitting of experimental data, viscosity of fluids, a robot arm, and thermal diffusion. C++ programming and graphical programming with LabVIEW™ are used for computer interfacing to hardware. Students develop effective written communication skills in the context of science and engineering. They prepare progress reports, technical reports, and formal articles based on the experiments.

ENGRD 270(2700) Basic Engineering Probability and Statistics

Fall, spring, summer. 3 credits. Prerequisites: MATH 191 and 192. MATH 294 should be completed before or concurrently with ENGRD 270.

Gives students a working knowledge of basic probability and statistics and their application to engineering. Includes computer analysis of data and simulation. Topics include random variables, probability distributions, expectation, estimation, testing, experimental design, quality control, and regression.

ENGRD 320(3200) Engineering Computation (also CEE 320[3200]) (formerly CEE 241)

Spring. 3 credits. Prerequisites: CS 100 and MATH 293. Corequisite: MATH 294. Recommended: completion of MATH 294. C. A. Shoemaker.

Introduction to numerical methods, computational mathematics, and probability and statistics. Development of programming and graphics proficiency with MATLAB and spreadsheets. Topics include: Taylor-series approximations, numerical errors, condition numbers, operation counts, convergence, and stability, probability distributions, hypothesis testing. Included are numerical methods for solving engineering problems that entail roots of functions, simultaneous linear equations, statistics, regression, interpolation, numerical differentiation and integration, and solution of ordinary and partial differential equations, including an introduction to finite difference methods. Applications are drawn from different areas of engineering. A group project uses these methods on a realistic engineering problem.

[ENGRD 321(3510) Numerical Methods in Computational Molecular Biology (also BIOBM 321[3210], CS 321[3510])

Fall. 3 credits. Prerequisites: at least one calculus course (e.g., MATH 106, 111, or 191) and a linear algebra course (e.g., MATH 221 or 294 or BTRY 417); CS 100 or equivalent and some familiarity with iteration, arrays, and procedures; knowledge of discrete probability and random variables at the level of CS 280.

An introduction to numerical computing using MATLAB organized around five applications: the analysis of protein shapes, dynamics, protein folding, score functions, and field equations. Students become adept at plotting, solving linear equations, least squares fitting, and cubic spline interpolation. More advanced problem-solving techniques that involve eigenvalue analysis, the solution of ordinary and partial differential equations, linear programming, and nonlinear minimization are also treated. The goal of the course is to develop a practical computational expertise with MATLAB and to build mathematical intuition for the problems of molecular biology.]

ENGRD 322(3220) Introduction to Scientific Computation (also CS 322[3220])

Spring, summer. 3 credits. Prerequisites: CS 100 and MATH 221 or 294; knowledge of discrete probability and random variables at the level of CS 280.

An introduction to elementary numerical analysis and scientific computation. Topics include interpolation, quadrature, linear and nonlinear equation solving, least-squares fitting, and ordinary differential equations. Uses the MATLAB computing environment. Stresses sectorization, efficiency, reliability, and stability. Special lectures cover computational statistics.

Courses of General Interest

Courses in this category are of general interest and cover technical, historical, and social issues relevant to the engineering profession. These courses may also include seminar or tutorial type courses.

ENGRG 100J(1000J) Cooperative Workshop for CS 100J(1000J)

Fall, spring. 1 credit. Corequisite: CS 100J. S-U grades only.

Academic Excellence Workshop for CS 100J. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in CS 100J.

ENGRG 100M(1000M) Cooperative Workshop for CS 100M(1000M)

Fall, spring. 1 credit. Corequisite: CS 100M. S-U grades only.

Academic Excellence Workshop for CS 100M. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in CS 100M.

ENGRG 150(1050) Engineering Seminar

Fall. 1 credit. Prerequisite: freshman standing. S-U grades only.

First-year engineering students meet in groups of 18 to 20 students weekly with their faculty advisors. Discussions may include the engineering curriculum and student programs, what engineers do, the character of engineering careers, active research areas in the college and in engineering in general, and study and examination skills useful for engineering students. Groups may visit campus academic, engineering, and research facilities.

ENGRG 160(1060) Exploration in Engineering Seminar

Summer. 1 credit. Designed for junior and senior high-school students.

Introduction to several engineering fields, such as: bioengineering, chemical engineering, civil engineering, computer science, earth sciences, electrical and computer engineering, engineering physics, materials science, mechanical engineering, operations research. Hands-on experience in weekly labs, as well as design projects to introduce concepts of the engineering design process.

ENGRG 191(1091) Cooperative Workshop for MATH 191(1910)

Fall. 1 credit. Corequisite: MATH 191. S-U grades only.

Academic Excellence Workshop for MATH 191. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in MATH 191.

ENGRG 192(1092) Cooperative Workshop for MATH 192(1920)

Fall, spring. 1 credit. Corequisite: MATH 192. S-U grades only.

Academic Excellence Workshop for MATH 192. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in MATH 192.

ENGRG 211(1011) Cooperative Workshop for CS 211(2110)

Fall, spring. 1 credit. Corequisite: CS 211. S-U grades only.

Academic Excellence Workshop for CS 211. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in CS 211.

ENGRG 209(1009) Cooperative Workshop for CHEM 209(2110)

Fall, spring. 1 credit. Corequisite: CHEM 209. S-U grades only.

Academic Excellence Workshop for CHEM 209. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in CHEM 209.

ENGRG 235(2350) Career Development for Engineering

Spring. 2 credits. Prerequisite: second-semester freshman or sophomore standing.

Introduces concepts and techniques that can be used now and in the future to set appropriate personal and professional career goals.

[ENGRG 250(2500) Technology in Society (also ECE/HIST 250[2500], S&TS 250[2501])

Fall. 3 credits. Approved for humanities distribution. Next offered 2008–2009.

Investigates the history of technology in Europe and the United States from ancient times to the present. Topics include the economic and social aspects of industrialization; the myths of heroic inventors like Morse, Edison, and Ford; the government's regulation of technology; the origins of mass production; and the spread of the automobile and microelectronics cultures in the United States.]

ENGRG 293(1093) Cooperative Workshop for MATH 293(2930)

Fall, spring. 1 credit. Corequisite: MATH 293. S-U grades only.

Academic Excellence Workshop for MATH 293. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in MATH 293.

ENGRG 294(1094) Cooperative Workshop for MATH 294(2940)

Fall, spring. 1 credit. Corequisite: MATH 294. S-U grades only.

Academic Excellence Workshop for MATH 294. Weekly two-hour cooperative learning sessions. Peer-facilitated group works on problems at or above the level of course material, designed to enhance understanding of core concepts in MATH 294.

[ENGRG 298(2980) Inventing an Information Society (also ECE 298[2980], AM ST 292[2980], HIST 292[2920], S&TS 292[2921], INFO 292[2921])

Spring. 3 credits. Approved for humanities distribution. Next offered 2008–2009.

Explores the history of information technology from the 1830s to the present by considering the technical and social history of telecommunications, the electric-power industry, radio, television, computers, and the Internet. Emphasis is on the changing relationship between science and technology, the economic aspects of innovation, gender and technology, and other social relations of this technology.]

ENGRG 323(3230) Engineering Economics and Management (also CEE 323[3230])

Spring, usually offered in summer for Engineering Co-op Program. 3 credits. Primarily for juniors and seniors. Students must register under CEE 323. D. P. Loucks.

Introduction to engineering and business economics investment alternatives and to project management. Intended to give students a working knowledge of money management and how to make economic comparisons of alternatives involving future benefits and cost. The impact of inflation, taxation, depreciation, financial planning, economic optimization, project scheduling, and legal and regulatory issues are introduced and applied to economic investment and planning and project-management problems.

[ENGRG 357(3570) Engineering in American Culture (also AM ST 356[3570], S&TS 357[3571], HIST 357[3570])

Fall. 4 credits. Approved for humanities distribution. Next offered 2008–2009.

The history of engineering in the United States from 1800 to the present. Investigates the education of engineers, how engineering changed from a masculine profession to one more open to women, the building of monumental projects, public images of the engineer, enthusiasm and disasters, and engineering in a global setting.]

ENGRG 360(3600) Ethical and Social Issues in Engineering (also S&TS 360[3601]) (KCM)

Spring. 3 credits. Open to sophomores.

Studies major ethical and social issues involved in engineering practice. The issues include responsibility for designing products that do not harm public health, safety, and welfare; rights of engineers in large corporations; risk analysis and the principle of informed consent; conflict of interest; whistle blowing; trade secrets; and broader concerns such as environmental degradation, cost of health care, computer ethics, and working in multinational corporations. Codes of ethics of the professional engineering societies, ethical theory, and the history and sociology of engineering are introduced to analyze these issues.

ENGRG 461(4610) Entrepreneurship for Engineers (also M&AE 461[4610], OR&IE 452[4152])

Fall. 3 credits. Prerequisite: upper-class engineers or permission of instructor. Staff.

For description, see M&AE 461.

ENGRG 678(6780) Teaching Seminar

Fall, spring. 1 credit. S-U grades only. Staff.

Independent study promoting reflection on teaching styles and experiences for teaching assistants in the College of Engineering. Participants must be concurrently fulfilling a TA assignment. Requirements include participation in the College of Engineering's TA Development Program, consisting of an initial one and one-half day training session, followed by one evening microteaching session early in the semester; participation in the TA midterm evaluation process, followed by a formal feedback session with program staff; and completion of a reflective journal on teaching experiences. Designed to provide TAs with the opportunity to process their understanding of teaching and learning through the formulation of questions, concepts, and theories related to their experiences.

Introduction to Engineering Courses

Courses in this category are freshman-level courses intended to introduce students to various aspects of engineering. They have no prerequisites and are always cross-listed with a department.

ENGRI 102(1020) Introduction to Nanoscience and Nanoengineering (also A&EP 102[1020])

Fall. 3 credits. Staff.

Lecture/laboratory course designed to introduce freshmen to some of the ideas and concepts of nanoscience and nanotechnology. Topics include nanoscience and nanotechnology—what they are and why they are of interest; atoms and molecules; the solid state; surfaces; behavior of light and material particles when confined to nanoscale dimensions; scanning tunneling microscopy (STM), atomic force microscopy (AFM), microelectromechanical systems (MEMS) design; basic micromachining and chemical synthesis methods, i.e., "top-down" and "bottom-up" approaches to nanofabrication; how to manipulate structures on the nanoscale; physical laws and limits they place on the nanoworld; some far-out ideas. In the laboratory, students use an AFM to record atomic resolution images, use a MEMS computer-aided design software package to model the entire manufacturing sequence of a simple MEMS device, examine the simulated behavior of the device and compare it with real behavior, construct a simple STM and learn through hands on experience the basic workings of the device.

ENGRI 110(1100) Lasers and Photonics (also A&EP 110[1100])

Fall, spring. 3 credits. F. Wise.

Lasers have had an enormous impact on communications, medicine, remote sensing, and material processing. This course reviews the properties of light that are essential to understanding the underlying principles of lasers and these photonic technologies. There also is a strong, hands-on laboratory component in which the students build and operate a nitrogen laser and participate in several demonstration experiments such as holography, laser processing of materials, optical tweezers, and fiber optics.

ENGRI 111(1110) Nanotechnology (also MS&E 111[1110])

Fall. 3 credits. E. Giannelis.

Nanotechnology has been enabling the Information Revolution with the development of even faster and more powerful devices for manipulation, storing, and transmitting information. In this hands-on course students learn how to design and manipulate materials to build devices and structures in applications ranging from computers to telecommunications to biotechnology.

ENGRI 112(1120) Introduction to Chemical Engineering (also CHEME 112[1120])

Fall. 3 credits. Prerequisite: freshman standing. T. M. Duncan.

Design and analysis of processes involving chemical change. Students learn strategies for design, such as creative thinking, conceptual blockbusting, and (re)definition of the design goal, in the context of contemporary chemical and biomolecular engineering. Includes methods for analyzing designs, such as mathematical modeling, empirical analysis by graphics, and dynamic scaling through dimensional analysis, to assess product quality, economics, safety, and environmental issues.

ENGRI 113(1130) Sustainability Design for Appledore Island

Spring. 3 credits. J. J. Bisogni.

The course utilizes a unique environment, Appledore island, as an example of how sustainability is addressed in the design of basic components of the built environment; energy, water supply and waste treatment. Students will present preliminary designs of sustainable systems to the engineering staff of Appledore Island. Students learn how to design: reservoirs to provide water during droughts, aqueducts to transport water, and water treatment plants to prevent waterborne diseases. The course includes field trips, building a computer-controlled miniature water treatment plant, and exploring new technologies for making safe drinking water.

ENGRI 115(1101) Engineering Applications of Operations Research

Fall, spring. 3 credits. Not open to OR&IE upper-class majors.

Introduction to the problems and methods of operations research and industrial engineering focusing on problem areas (including inventory, network design, and resource allocation), the situations in which these problems arise, and several standard solution techniques. In the computational laboratory, students encounter problem simulations and use some standard commercial software packages.

ENGRI 116(1160) Modern Structures (also CEE 116[1160])

Fall. 3 credits. A. Ingraffea.

Introduction to structural engineering in the 21st century—the challenges structural engineers face and the innovative approaches they are using to address them. Using case studies of famous structures, students learn to identify different structural forms and understand how various forms carry load-using principles of statics, mechanics, and material behavior. The historical, economic, social, and political context for each structure is discussed. Case studies of failures are used to explain how structures fail in earthquakes and other extreme events, and students are introduced to analytical and experimental approaches (shake table and wind tunnel testing) to quantifying loads on structures subjected to extreme events. Types of structures considered include skyscrapers, bridges, aircraft, and underground structures.

ENGRI 117(1170) Introduction to Mechanical Engineering (also M&AE 117[1170])

Fall. 3 credits.

Introduction to fundamentals of mechanical and aerospace engineering. Students learn and understand materials characteristics, the behavior of materials, and material selection for performing engineering function. They also learn fundamentals of fluid mechanics, heat transfer, automotive engineering, engineering design and product development, patents and intellectual property, and engineering ethics. In the final project, students use the information learned to design and manufacture a product.

[ENGRI 118(1180) Design Integration: DVDs and iPods (also T&AM 118[1180])

Spring. 3 credits. Next offered 2008–2009. W. Sachse.

This course examines the broad range of systems and engineering technologies required to build today's remarkable music/data and video sources.]

ENGRI 119(1190) Biomaterials for the Skeletal System (also MS&E 119[1190])

Fall. 3 credits. D. Grubb.

Biomaterials are at the intersection of biology and engineering. This course explores natural structural materials in the human body, their properties and microstructure, and their synthetic and semi-synthetic replacements. Bones, joints, teeth, tendons, and ligaments are used as examples, with their metal, plastic, and ceramic replacements. Topics include strength, corrosion, toxicity, wear, and bio-compatibility. Case studies of design lead to consideration of regulatory approval requirements and legal liability issues.

ENGRI 122(1120) Earthquake! (also EAS 122[1220])

Spring. 3 credits. L. Brown.

Explores the science of natural hazards and strategic resources. Covers techniques for locating and characterizing earthquakes, and assesses the damage they cause; methods of using sound waves to image the earth's interior to search for strategic materials; and the historical importance of such resources. Includes seismic experiments on campus to probe for groundwater, the new critical environmental resource.

ENGRI 126(1260) Introduction to Signals and Telecommunications

Spring. 3 credits.

Introduces the concepts that underlie wired and wireless communication systems. Students achieve a rudimentary understanding of basic ideas such as coding and data compression; frequency content, bandwidth, and filtering; sampling and reconstruction; and time- and frequency-division multiplexing. Discussions of practical applications focus on areas such as the public switched telephone network, ISDN, ATM, and TCP/IP. Students also develop an appreciation for the historical development of the field. The course includes both lectures and laboratory demonstrations.

ENGRI 127(1270) Introduction to Entrepreneurship and Enterprise Engineering (also M&AE 127[1270])

Spring. 3 credits. Open to all Cornell students regardless of major. Prerequisite: none.

Provides a solid introduction to the entrepreneurial process to students in engineering. The main objective is to identify and to begin to develop skills in the engineering work that occurs in high-growth, high-tech ventures. Basic engineering management issues, including the entrepreneurial perspective, opportunity recognition and evaluation, and gathering and managing resources are covered. Technical topics such as the engineering design process, product realization, and technology forecasting are discussed.

ENGRI 131(1310) Introduction to Biomedical Engineering (also BME 131[1310])

Spring. 3 credits. Prerequisite: freshman or sophomore standing. C. B. Schaffer and S. D. Archer.

Modern biology and medicine is undergoing a revolution as quantitative principles of measurement, analysis, and design are introduced to help solve a variety of scientific and medical problems. This course will provide an introduction to the study of biological systems with a quantitative perspective from the molecular to the cellular to the organism scale, as well as to the design of practical devices for studying biological systems and treating disease. Collaborative work will be a key element in all aspects of the course, from the lectures and labs, to the assignments and term project.

ENGRI 165(1610) Computing in the Arts (also ART 175, CIS 165[1610], CS 165[1610], MUSIC 165[1465], PSYCH 165[1650])

Fall. 3 credits. Complements ART 171+ and MUSIC 120+. S-U or letter grades.

For description, see CS 165.

ENGRI 167(1670) Visual Imaging in the Electronic Age (also ART 170[1700], CIS 167[1620], CS 167[1620])

Fall. 3 credits. S-U or letter grades. Staff.

For description, see ART 170.

[ENGRI 172(1700) Computation, Information, and Intelligence (also COGST 172, CS 172[1700], INFO 172[1700])

Fall or spring. 3 credits. Prerequisites: some knowledge of differentiation; freshman standing or permission of instructor. Next offered 2008–2009.

For description, see CS 172 in CIS section.]

APPLIED AND ENGINEERING PHYSICS

J. D. Brock, director; A. L. Gaeta, associate director; L. Pollack, director of undergraduate studies; F. W. Wise, director of graduate studies; R. A. Buhrman, T. A. Cool, H. G. Craighead, A. L. Gaeta, V. O. Kostroun, M. Lindau, R. V. E. Lovelace, D. Muller, L. Pollack, J. Silcox, W. W. Webb, C. Xu. Adjunct faculty: D. H. Bilderback, Q. Hao, S. Heinekamp. Senior research associate: E. J. Kirkland. Instructor: M. J. Plisch. Lecturer: L. Wickham

A&EP 102(1020) Introduction to Nanoscience and Nanoengineering (also ENGRI 102[1020])

Fall, spring. 3 credits.

Course in Introduction to Engineering series. For description, see ENGRI 130.

A&EP 110(1110) Lasers and Photonics (also ENGRI 110[1100])

Fall. 3 credits. F. Wise.

Course in Introduction to Engineering series. For description, see ENGRI 110.

A&EP 217(2170) Electricity and Magnetism (also PHYS 217[2217])

Fall, spring. 4 credits. Prerequisites: permission of advisor and instructor; co-registration in PHYS 216 or knowledge of special relativity at level of PHYS 116; MATH 192 or equivalent and co-registration in MATH 293 or equivalent. Staff.

Intended for students who have done well in PHYS 112 or 116 (or equivalent) and mathematics and who desire a more analytic treatment than that of PHYS 213. At the level of *Electricity and Magnetism* by Purcell. Recommended for prospective engineering physics majors. Placement quiz may be given early in semester, permitting students who find material too abstract or analytical to transfer into PHYS 213 without difficulty.

A&EP 252(2520) The Physics of Life (also ENGRD 252[2520])

Fall. Prerequisites: MATH 192, CHEM 207 or 211, and co-registration in or completion of PHYS 213. L. Pollack.

For description, see ENGRD 252.

A&EP 264(2640) Computer-Instrumentation Design (also ENGRD 264[2640])

Fall, spring. 3 credits. Prerequisites: seniors by permission of instructor; CS 100. 1 lec, 1 lab.

For description, see ENGRD 264.

A&EP 321(3210) Mathematical Physics I

Fall, summer. 4 credits. Prerequisite: MATH 294. Intended for upper-level undergraduates in physical sciences. B. Kusse.

Review of vector analysis; complex variable theory, Cauchy-Rieman conditions, complex Taylor and Laurent series, Cauchy integral formula and residue techniques, conformal mapping; Fourier Series; Fourier and Laplace transforms; ordinary differential equations; separation of variables. Texts: *Mathematical Methods for Physicists* by Arfken and *Mathematical Physics* by Butkov.

A&EP 322(3220) Mathematical Physics II
Spring. 4 credits. Prerequisite: A&EP 321. Second of two-course sequence in mathematical physics intended for upper-level undergraduates in physical sciences. B. Kusse.
Topics include partial differential equations, Bessel functions, spherical harmonics, separation of variables, wave and diffusion equations, Laplace, Helmholtz, and Poisson's Equations, transform techniques, Green's functions; integral equations, Fredholm equations, kernals; complex variables, theory, branch points and cuts, Riemann sheets, method of steepest descent; tensors, contravariant, and covariant representations; group theory, matrix representations, class and character. Texts: *Mathematical Methods for Physicists* by Arfken and *Mathematical Physics* by Butkov.

A&EP 324(3240) Maple Supplement to Mathematical Physics 321 and 322
Spring. 1 credit. R. V. E. Lovelace.
A broad introduction to Maple in applications to problems of mathematical physics similar to those covered in A&EP 321 and 322. Uses Maple to solve differential equations—both linear and nonlinear. Makes extensive use of plotting capabilities of Maple. Also covers matrices, complex functions, Laplace and Fourier transforms (and FFTs), and group theory. Gives an introduction to LaTex.

A&EP 330(3330) Modern Experimental Optics (also PHYS 330[3300])
Fall. 4 credits. Limited enrollment. Prerequisite: PHYS 214 or equivalent. E. Bodenschatz.
Practical laboratory course in basic and modern optics. The various projects cover a wide range of topics from geometrical optics to classical wave properties such as interference, diffraction, and polarization. Each experimental setup is equipped with standard, off-the-shelf optics and opto-mechanical components to provide the students with hands-on experience in practical laboratory techniques currently employed in physics, chemistry, biology, and engineering. Students are also introduced to digital imaging and image processing techniques.

A&EP 333(3330) Mechanics of Particles and Solid Bodies
Fall, summer. 4 credits. Prerequisites: PHYS 112 or 116 and co-registration in A&EP 321 or equivalent or permission of instructor. Staff.
Covers Newton's mechanics; constants of the motion; many-body systems; linear oscillations; variational calculus; Lagrangian and Hamiltonian formalism for generalized coordinates; non-inertial reference systems; central-force motion; motion of rigid bodies; small vibrations in multi-mass systems; nonlinear oscillations; and basic introduction to relativistic mechanics. Emphasis is on mathematical treatments, physical concepts, and applications. (At the level of *Classical Dynamics* by Marion and Thorton.)

A&EP 355(3550) Intermediate Electromagnetism
Fall, summer; first half of semester. 2 credits. Prerequisite: PHYS 213 or 217 and co-registration with A&EP 321, or permission of instructor.
Intermediate-level course on electromagnetic theory with a focus on statics. Vector calculus, electrostatics, conductors, dielectric materials, boundary conditions, solutions to Laplace's equation, and magnetostatics. Emphasis is on developing proficiency with analytical techniques and intuitive understanding of fundamental electromagnetism.

A&EP 356(3560) Intermediate Electrodynamics
Spring. 4 credits. Prerequisite: A&EP 355 and co-registration with A&EP 322, or permission of instructor.
Second course in theory of electromagnetism. Magnetic materials, Faraday's law, Maxwell equations, electromagnetic waves, reflection and transmission, guided waves, and radiation.

A&EP 361(3610) Introductory Quantum Mechanics
Fall, summer; second half of semester. 2 credits. Prerequisites: PHYS 213 or 217 and co-registration with A&EP 321, or permission of instructor.
Introductory course on the theory of quantum mechanics. Topics include waves, Schrödinger's equation and the concept of the wavefunction, simple potentials, and the harmonic oscillator model. Emphasis is on developing an intuitive understanding of quantum mechanics.

A&EP 362(3620) Intermediate Quantum Mechanics
Spring, 4 credits. Prerequisite: PHYS 361 or 316 and co-registration with A&EP 322 or permission of instructor.
Continuation of A&EP 361 covering more advanced material in quantum mechanics. Topics include operator formalism and matrix representation, angular momentum and spin, the hydrogen atom, techniques for solving Schrödinger's equation including perturbation theory, two- and three-level systems, interaction with radiation, and identical particles.

A&EP 363(3630) Electronic Circuits (also PHYS 360[3360])
Fall, spring. 4 credits. Prerequisites: PHYS 208 or 213 or permission of instructor. No previous experience with electronics assumed; however, course moves quickly through introductory topics such as basic DC circuits. Fall semester usually less crowded. 1 lec, 2 labs. Fall: E. Kirkland; spring: J. Alexander.
Students analyze, design, build, and experimentally test circuits used in scientific and engineering instrumentation (with discrete components and integrated circuits). Analog circuits: resistors, capacitors, operational amplifiers (linear amplifiers with feedback, oscillators, comparators), filters, diodes, and transistors. Digital circuits: combinatorial (gates) and sequential (flip-flops, counters, shift registers) logic. Computer interfacing introduced and used to investigate digital to analog (DAC) and analog to digital conversion (ADC) and signal averaging.

A&EP 423(4230) Statistical Thermodynamics
Fall. 4 credits. Prerequisite: introductory three-semester physics sequence, familiarity with quantum mechanics (A&EP 361 or PHYS 316) and one year junior-level mathematics. Staff.
Quantum statistical basis for equilibrium thermodynamics, microcanonical, canonical and grand canonical ensembles, and partition functions. Classical and quantum ideal gases, paramagnetic and multiple-state systems. Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics and applications. Introduction to systems of interacting particles. At the level of *Introductory Statistical Mechanics* by Bowley and Sanchez.

A&EP 434(4340) Continuum Physics
Spring. 4 credits. Prerequisites: A&EP 333 and 356 or equivalent. Staff.
Topics: Elasticity and Fluid Mechanics: basic phenomena of elasticity, simple beams, stress and strain tensors, materials equations, equations of motion, general beam equations, waves; fluids: basic phenomena, Navier Stokes equation, scaling laws, Reynolds and Froude numbers, Poisseuille flows, Stokes drag on sphere, boundary layers, invicid and incompressible flows, potential flow, conservation laws, Bernoulli equation, vorticity and circulation, life of wings, jets, instabilities, introduction to turbulence. Projects in combination with A&EP 438 possible. At the level of *Continuum Mechanics* by Lai, Rubin, and Krempl and *Introduction to Fluid Mechanics* by Tritton.

A&EP 438(4380) Computational Engineering Physics
Spring. 3 credits. Prerequisites: CS 100, A&EP 321, 333, 355, 361, or equivalent, or permission of instructor; co-registration in 361 permitted. Staff.
Numerical computation (e.g., derivatives, integrals, differential equations, matrices, boundary-value problems, relaxation, Monte Carlo methods) is introduced and applied to engineering physics problems that cannot be solved analytically (e.g., three-body problem, electrostatic fields, quantum energy levels). Computer programming required (in C or optionally C++, FORTRAN, or Pascal). Some prior exposure to programming assumed but no previous experience with C assumed.

A&EP 440(4440) Quantum and Nonlinear Optics
Spring. 4 credits. Prerequisites: A&EP 356, 361, or equivalent. Staff.
Introduction to the fundamentals of the interaction of laser light with matter and to optical devices based on these processes. Topics include the propagation of laser beams in bulk media and guided-wave structures, the origins of optical nonlinearities, harmonic generation, parametric amplification, self-focusing, optical switching, propagation of ultrashort pulses, solitons, four-wave mixing, optical phase conjugation, optical resonance and two-level atoms, atom cooling and trapping, multiphoton processes, spontaneous and simulated scattering, and ultra-intense laser-matter interactions.

A&EP 450(4500) Introductory Solid State Physics (also PHYS 454[4454])
Fall. 4 credits. Highly recommended: some exposure to quantum mechanics at level of PHYS 443, A&EP 361, or CHEM 793. Staff.
Introduction the physics of crystalline solids. Covers crystal structures; electronic states; lattice vibrations; and metals, insulators, and semiconductors. Computer simulations of the dynamics of electrons and ions in solids. Covers optical properties, magnetism, and superconductivity as time allows. The majority of the course addresses the foundations of the subject, but time is devoted to modern and/or technologically important topics such as quantum size effects. At the level of *Introduction to Solid State Physics* by Kittel or *Solid State Physics* by Ashcroft and Mermun.

A&EP 470(4700) Biophysical Methods (also BIONB 470[4700])
Fall. 3 credits. Prerequisites: solid knowledge of basic physics and mathematics through sophomore level. Recommended: some knowledge of cellular biology. Letter grades only.
Overview of the diversity of modern biophysical experimental techniques used in the study of biophysical systems at the cellular and molecular level. Topics include methods that examine both structure and function of biological systems, with emphasis on the applications of these methods to biological membranes. The course format includes assigned literature reviews by the students on specific biophysics topics and individual student presentations on these topics. The course is intended for students of the engineering, physics, chemistry, and biological disciplines who seek an introduction to modern biophysical experimental methods.

A&EP 484(4840) Introduction to Controlled Fusion: Principles and Technology (also ECE/NS&E 484[4840], M&AE 459[4590])
Spring. 3 credits. On demand. Prerequisites: PHYS 112, 213, and 214, or equivalent background in electricity and magnetism and mechanics; and permission of instructor. Intended for seniors and graduate students.
For description, see NS&E 484.

A&EP 490–491(4900–4910) Independent Study in Engineering Physics
Fall, spring. Credit TBA.
Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the faculty. The study can take a number of forms; for example, design of laboratory apparatus, performance of laboratory measurements, computer simulation or software developments, theoretical design and analysis. Details TBA with respective faculty member.

A&EP 550(5500) Applied Solid State Physics
Spring. 3 credits. Prerequisites: A&EP 356, 361, 423, 450 or equivalent.
Directed at students who have had an introductory course in solid state physics at the level of Kittel. Concentrates on the application of the quantum mechanical theory of solid state physics to semiconductor materials, solid state electronic devices, solid state detectors and generators of electromagnetic radiation, superconducting devices and materials, the nonlinear optical properties of solids, ferromagnetic materials, nanoscale devices, and mesoscopic quantum mechanical effects. The course stresses the basic, fundamental physics underlying the applications rather than the applications themselves. At the level of *Introduction to Applied Solid State Physics* by Dalven.

A&EP 571(5710) Biophysical Methods Advanced Laboratory
Spring, first three weeks of Jan. or TBA during spring semester. 3 credits. Prerequisite: A&EP 470 highly recommended but qualified students who have not taken A&EP 470 also accepted. Letter or S-U grades. M. Lindau.
Offered to students in the engineering, physics, chemistry and biological disciplines who are interested in research at the interface between physical sciences/engineering and life sciences. In groups of two, participants perform five experiments in research laboratories on state-of-the-art equipment. Lab training sessions are arranged individually in January and throughout the spring semester. Typically each experiment is two days in the lab plus one day for analysis and report writing. The course is intended for students who seek hands-on introduction to modern biophysical experimental methods.

A&EP 607(6070) Advanced Plasma Physics (also ECE 582[5820])
Spring. On demand. 4 credits. Prerequisites: ECE 581 and A&EP 606.
For description, see ECE 582.

A&EP 633(6330) Nuclear Reactor Engineering (also NS&E 633[6330])
Fall. 4 credits. Prerequisite: introductory course in nuclear engineering. Offered on demand. K. B. Cady.
For description, see NS&E 633.

A&EP 661(6610) Nanocharacterization
Fall. 3 credits. Prerequisites: Fourier transforms, basic electromagnetism, and undergraduate quantum mechanics or chemistry. Undergraduates should consult with instructor before enrolling.
Graduate-level introduction to the tools used to image and probe optical, electronic, chemical, and mechanical properties at the nanoscale and below. Discussion centers on the physics of the interaction processes used for characterization, quantification, and interpretation of the collected signals, common artifacts, the engineering trade-offs made in constructing the actual instruments, and the fundamental detection limits for each method. Topics include the interaction of electrons, ions, and photons with materials; scanned probe and force microscopy; scanning and transmission electron microscopy; x-ray microanalysis; electron energy loss spectroscopy; and a brief survey of non-imaging methods such as RBS, XPS, and SIMS.

A&EP 662(6620) Micro/Nano-fabrication and Processing
Spring. 3 credits.
Introduction to the fundamentals of micro- and nano-fabricating and patterning thin-film materials and surfaces, with emphasis on electronic and optical materials, micromechanics, and other applications. Vacuum and plasma thin-film deposition processes. Photon, electron, X-ray, and ion-beam lithography. Techniques for pattern replication by plasma and ion processes. Emphasis is on understanding the physics and materials science that define and limit the various processes. At the level of Brodie and Muray.

A&EP 663(6630) Nanobiotechnology (also BIO G 663[6630], MS&E 563[5630])
Spring. 3 credits. Letter grades only.
Upper-level undergraduate and graduate-level course that covers the basics of biology and the principles and practice of microfabrication techniques. The course focuses on applications in biomedical and biological research. A team design project that stresses interdisciplinary communication and problem solving is one of the course requirements. The course meets twice weekly with 75-minute classes. All lectures are teleconferenced to NBTC associate institutes.

A&EP 711(7110) Principles of Diffraction (also MS&E 671[6710])
Fall. 3 credits. Letter grades only. J. D. Brock.
Graduate-level introduction to diffraction/scattering phenomena in the context of solid-state and soft condensed-matter systems. The primary topic is using the scattering and absorption of neutron, electron, and X-ray beams to study physical systems. Particular emphasis is placed on issues related to synchrotron X-ray sources. Specific topics that are covered in the course include: elastic and inelastic scattering; diffraction from two- and three-dimensional periodic lattices; the Fourier representation of scattering centers and the effects of thermal vibrations and disorder; diffraction, reflectivity, or scattering from surface layers; diffraction or scattering from gases and amorphous materials; small angle scattering; X-ray absorption spectroscopy; resonant (e.g., magnetic) scattering; novel techniques using coherent X-ray beams; and a survey of dynamical diffraction from perfect and imperfect lattices.

A&EP 751(7510) M.Eng. Project
Fall, spring. 6–12 credits TBA. Requirement for M.Eng. (engineering physics) students.
Independent study under the direction of a member of the university faculty. Students participate in an independent research project through work on a special problem related to their field of interest. A formal and complete research report is required.

A&EP 753(7530) Special Topics Seminar in Applied Physics
Fall. 1 credit. Requirement for M.Eng. (engineering physics) students; recommended for seniors in engineering physics. Prerequisite: undergraduate physics.
Special topics in applied science, with focus on areas of applied physics and engineering that are of current interest. Subjects chosen are researched in the library and presented in a seminar format by the students. Effort is made to integrate the subjects within selected subject areas such as atomic, biological, computational, optical, plasma, and solid-state physics, or microfabrication technology, as suggested by the students and coordinated by the instructor.

[A&EP 781(7810) Advanced Plasma Physics I: Cosmic Plasma Physics]

A&EP 782(7820) Advanced Plasma Physics (also ECE 682[6820])
Spring. 3 credits. Prerequisite: ECE 581. C. E. Seyler.
For description, see ECE 682.

BIOLOGICAL AND ENVIRONMENTAL ENGINEERING

M. F. Walter, chair; B. A. Ahner, L. D. Albright, D. J. Aneshansley, A. J. Baeumner, J. A. Bartsch, A. K. Datta, K. G. Gebremedhin, R. C. Gorewit, D. A. Haith, P. Hess, J. B. Hunter, L. H. Irwin, W. J. Jewell, D. Luo, J. C. March, J.-Y. Parlange, N. R. Scott, R. M. Spanswick, T. S. Steenhuis, M. B. Timmons, L. P. Walker, M. T. Walter. Lecturers: C. L. Anderson, T. J. Cook, L. D. Geohring, P. E. Hillman

For complete course descriptions, see "Biological and Environmental Engineering" under "College of Agriculture and Life

Sciences" or visit the department web site, www.bee.cornell.edu.

BEE 110(1030) Introduction to Metal Fabrication Techniques
Spring. 3 credits. Limited to 20 students per lab.

BEE 132(1040) Introduction to Wood Construction
Fall. 3 credits. Limited to 16 students per lab.

BEE 151(1510) Introduction to Computer Programming
Fall. 4 credits. Limited to 18 students per lab and rec. Pre- or corequisite: MATH 191 or equivalent. No previous programming experience assumed.

BEE 200(1200) The BEE Experience
Spring. 1 credit. Requirement for CALS BEE freshmen. Not required for students who have completed ENGRG 150. Prerequisite: BEE majors or permission of instructor.

BEE 222(2220) Bioengineering Thermodynamics and Kinetics
Spring. 3 credits. Prerequisites: MATH 192, BIO G 110, PHYS 213, and chemistry course completed or concurrent.

BEE 251(2510) Engineering for a Sustainable Society (also ENGRD 251[2510])
Fall. 3 credits. Pre- or corequisite: MATH 293.

BEE 260(2600) Principles of Biological Engineering (also ENGRD 260[2600])
Fall. 3 credits. Pre- or corequisite: MATH 293.

BEE 299(3299) Sustainable Development: A Web-Based Course
Spring, summer. 3 credits. Prerequisite: at least sophomore standing. S-U or letter grades.

BEE 305(3050) Principles of Navigation (also NAV S 301[3050])
Spring. 4 credits. Three classes each week (lec-rec-project work).

BEE 310(1050) Advanced Metal Fabrication Techniques
Spring. 1–2 credits. Prerequisite: BEE 110 or permission of instructor.

BEE 331(3310) Bio-Fluid Mechanics
Fall. 4 credits. Prerequisites: ENGRD 202 and engineering math sequence.

BEE 350(3500) Biological and Environmental Transport Processes
Fall. 3 credits. Pre- or corequisites: MATH 293 and fluid mechanics course.

BEE 360(3600) Molecular and Cellular Bioengineering (also BME 360[3600])
Spring. 3 credits. Prerequisites: BEE 260, biochemistry, linear algebra, ordinary differential equations, or permission of instructor.

BEE 362(3620) Fundamentals of Tissue Engineering
Spring. 3 credits. Limited to 25 students. Prerequisites: biochemistry course, BEE 350. Priority given to graduating seniors.

BEE 365(3650) Properties of Biological Materials
Spring. 3 credits. Pre- or corequisite: ENGRD 202.

BEE 368(3680) Biotechnology Applications: Animal Bioreactors
Fall. 3 credits. Prerequisite: biochemistry course or permission of instructor.

[BEE 371(3710) Physical Hydrology for Ecosystems
Spring. 3 credits. Prerequisite: MATH 192 or permission of instructor. Offered alternate years; next offered 2008–2009.]

BEE 401(4010) Renewable Energy Systems
Spring. 3 credits. Prerequisite: college physics.

BEE 427(4270) Water Sampling and Measurement
Fall. 3 credits. Prerequisites: fluids or hydrology course and MATH 191.

BEE 435(4350) Principles of Aquaculture
Spring. 3 credits. Prerequisite: at least junior standing.

BEE 450(4500) Bioinstrumentation
Spring. 4 credits. Prerequisites: MATH 294, introductory computing, two semesters of physics, statistics, or permission of instructor.

BEE 453(4530) Computer-Aided Engineering: Applications to Biomedical Processes (also M&AE 453[4530])
Spring. 3 credits. Prerequisite: heat and mass transfer course (BEE 350 or equivalent).

BEE 454(4540) Physiological Engineering
Fall. 3 credits. Prerequisites: differential equations, two semesters of physics, introductory biology, statistics.

[BEE 459(4590) Biosensors and Bioanalytical Techniques
Fall. 3 credits. Prerequisite: biochemistry course or permission of instructor. Next offered 2008–2009.]

[BEE 464(4640) Bioseparation Processes
Fall. 3 credits. Prerequisites: introductory biochemistry and physics, MATH 192, BEE 260, or permission of instructor. Next offered 2008–2009.]

BEE 471(4710) Introduction to Groundwater (also EAS 471[4710])
Spring. 3 credits. Prerequisites: MATH 293, fluid mechanics or hydrology course.

BEE 473(4730) Watershed Engineering
Fall. 3 credits. Prerequisite: fluid mechanics or hydrology course.

BEE 474(4740) Water and Landscape Engineering Applications
Spring. 3 credits. Prerequisite: fluids or hydrology course or permission of instructor.

BEE 475(4750) Environmental Systems Analysis
Fall. 3 credits. Prerequisites: computer programming course and one year of calculus.

BEE 476(4760) Solid Waste Engineering
Spring. 3 credits. Prerequisites: one semester of physics and chemistry.

BEE 478(4780) Ecological Engineering
Spring. 3 credits. Prerequisite: junior-level environmental quality engineering course or equivalent.

BEE 481(4791) LRFD-Based Engineering of Wood Structures (also CEE 481[4781])
Spring. 3 credits. Prerequisite: ENGRD 202.

BEE 484(4840) Metabolic Engineering
Spring. 3 credits. Prerequisite: biochemistry course or permission of instructor.

BEE 487(4870) Sustainable Energy Systems
Fall. 3 credits. Prerequisites: BEE 350 and thermodynamics course.

BEE 489(4890) Engineering Entrepreneurship, Management, and Ethics
Spring. 4 credits. Prerequisites: ENGRD 270 or CEE 304 or equivalent; junior standing.

BEE 493(4930) Technical Writing for Engineers
Fall, spring. 1 credit. Corequisite: BEE 450 (spring), 473 (fall).

BEE 494(4940) Baja SAE (also M&AE 490, sec. 58)
Fall, spring. 1–4 credits. Prerequisite: permission of instructor.

BEE 494(4940) Introduction to Atmospheric Chemistry
Fall. 3 credits. Engineers must take for letter grade. Prerequisites: one year of chemistry, one year of calculus, one year of calculus-based physics or permission of instructor. S-U or letter grades.

BEE 495(4950) Honors Research
Fall, spring. 1–6 credits. Prerequisite: enrollment in BEE Honors Research Program.

BEE 496(4960) Capstone Design in Biological and Environmental Engineering
Fall, spring. 1 credit. Corequisite: BEE 435 or 473 or 478, or 481.

BEE 497(4970) Individual Study in Biological and Environmental Engineering
Fall, spring. 1–4 credits. Prerequisites: written permission of instructor and adequate ability and training for work proposed. Normally reserved for seniors in upper two-fifths of their class. Students from all colleges must register using independent study form (available in 207 Riley-Robb Hall).

BEE 498(4980) Undergraduate Teaching
Fall, spring. 1–4 credits. Prerequisite: written permission of instructor. Students from all colleges must register using independent study form (available in 207 Riley-Robb Hall).

BEE 499(4990) Undergraduate Research
Fall, spring. 1–4 credits. Prerequisites: written permission of instructor; adequate training for work proposed. Normally reserved for seniors in upper two-fifths of their class. Students from all colleges must register using independent study form (available in 207 Riley-Robb Hall).

BEE 501(5010) Bioengineering Seminar (also BME 501[5010])
Fall, spring. 1 credit. Prerequisite: junior, senior, or graduate standing. S-U grades only.

BEE 520(5900) M.P.S. Project
Fall, spring. 1–6 credits. Requirement for all M.P.S. candidates in field.

BEE 533(5330) Engineering Professionalism
Spring. 1–2 credits. Prerequisite: graduate student with accredited engineering degree or senior who will be graduate with accredited engineering degree. Must register to take Fundamentals of Engineering Exam. S-U or letter grades.

BEE 551(5950) Master of Engineering Design Project
Fall, spring. 3–6 credits. Prerequisite: admission to M.Eng. degree program.

BEE 647(6470) Water Transport in Plants (also BIOPL 651[6510])
Fall. 2 credits. Offered alternate years.

[BEE 649(6490) Solute Transport in Plants (also BIOPL 649[6490]
Fall. 3 credits. Offered alternate years; next offered 2008–2009.]

BEE 651(6510) Bioremediation: Engineering Organisms to Clean Up the Environment
Spring. 3 credits. Prerequisite: BIOMI 290 or BIOBM 331 or permission of instructor.

BEE 655(6550) Thermodynamics and Its Applications
Fall. 3 credits. Prerequisite: MATH 293 or equivalent; for undergraduates, permission of instructor. Offered alternate years.

[BEE 659(6590) Biosensors and Bioanalytical Techniques
Fall. 3 credits. Prerequisites: biochemistry course and permission of instructor. Next offered 2008–2009.]

[BEE 671(6710) Analysis of the Flow of Water and Chemicals in Soils
Fall. 3 credits. Prerequisites: four calculus courses and fluid mechanics course; for undergraduates, permission of instructor. Offered alternate years; next offered 2008–2009.]

[BEE 672(6720) Drainage
Spring. 4 credits. Prerequisite: BEE 471 or 473. Offered alternate years; next offered 2008–2009.]

BEE 674(6740) Ecohydrology
Spring. 3 credits. Prerequisite: ecohydrology or hydrology course. Offered alternate years.

BEE 687(6870) The Science and Engineering Challenges to the Development of Sustainable Bio-Based Industries
Fall. 1 credit. Prerequisite: graduate standing. S-U grades only.

BEE 697(6970) Graduate Individual Study in Biological and Environmental Engineering
Fall, spring. 1–6 credits. Prerequisite: permission of instructor. S-U or letter grades.

BEE 700(7010) BEE Seminar Series
Spring. 1 credit. S-U or letter grades.

BEE 740(6430) Veterinary Perspectives on Pathogen Control in Animal Manure (also VTMED 740[6430], BIOMI 740[6430])
Spring. 2 credits. Prerequisite: graduate standing or permission of instructor.

BEE 750(7000) Orientation to Graduate Study
Fall. 1 credit. Prerequisite: newly joining graduate students in BEE. S-U grades only.

BEE 754(7540) Water and Culture in the Mediterranean: A Crisis (also D SOC 694[6940])
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor. S-U or letter grades.

BEE 760(7600) Nucleic Acid Engineering (also BME 760[7600])
Spring. 2 credits. Prerequisite: graduate standing; seniors by permission of instructor. S-U or letter grades.

BEE 771(7710) Soil and Water Engineering Seminar
Fall, spring. 1 credit. Prerequisite: graduate standing or permission of instructor. S-U grades only.

BEE 787(7870) Industrial Ecology of Agriculturally Based Bioindustries
Spring. 3 credits. Prerequisites: one year calculus, MATLAB, BEE 687, graduate standing. Offered alternate years.

[BEE 788(7880) Biomass Conversion of Energy and Chemicals
Spring. 3 credits. Prerequisites: one year college calculus and chemistry; minimum of one course in thermodynamics and computer programming. Offered alternate years; next offered 2008–2009.]

BEE 800(8900) Master's-Level Thesis Research
Fall, spring. 1–15 credits. Prerequisite: permission of advisor. S-U grades only.

BEE 900(9900) Doctoral-Level Thesis Research
Fall, spring. 1–15 credits. Prerequisite: permission of advisor. S-U grades only.

BIOMEDICAL ENGINEERING

M. L. Shuler, James M. and Marsha McCormick chair; L. J. Bonassar, associate chair; D. L. Bartel, J. T. Butcher, P. C. Doerschuk, director of graduate studies, C. Fischbach-Teschl, M. Jin, W. L. Olbricht, D. A. Putnam, C. Reinhart-King, C. B. Schaffer, D. J. Skorton, Y. Wang, W. R. Zipfel. Senior lecturers: S. D. Archer, D. Lipson

BME 131(1310) Introduction to Biomedical Engineering (also ENGRI 131[1310])
Spring. 3 credits. Prerequisite: freshman or sophomore standing. C. B. Schaffer and S. D. Archer.
For description, see ENGRI 131.

BME 301(3010) Molecular Principles of Biomedical Engineering (also CHEME 401[4010])
Fall. 3 credits. Prerequisite: basic biology such as BIO G 110, BIOBM 330, or BIOMI 290. Lec and lab. M. Jin and S. D. Archer.
Introduction to genomics, proteomics, bioinformatics, and computational biology with an emphasis on the engineering challenges for these areas. Covers cytoskeletal and motor proteins and their relationship to nano- and micro-machines and nanobiotechnology. Existing and emerging technologies and instrumentation critical to molecular-level analysis in biomedical engineering.

BME 302(3020) Cellular Principles of Biomedical Engineering (also CHEME 402[4020])
Spring. 3 credits. Prerequisite: BME 301 or course work in basic biology such as BIO G 110, BIOBM 330, or BIOMI 290 plus mathematics through differential equations (e.g., MATH 221 or 294), or permission of instructor. Lec and lab. D. A. Putnam and S. D. Archer.
Integration of mammalian cell biology with engineering modeling principles, put into the context of medical pathology and disease states. Consists of three modules: (1) cell culture techniques/receptor ligand interactions, (2) cellular trafficking, and (3) signal transduction.

[BME 330(3300) Introduction to Computational Neuroscience (also BIONB/PSYCH/COGST 330[3300])
Fall. 3 or 4 credits; 4 credits includes lab providing additional computer simulation exercises. Limited to 25 students. Prerequisites: BIONB 222 or permission of instructor. S-U or letter grades. Offered alternate years; next offered 2008–2009. C. Linster.
For description, see BIONB 330.]

BME 360(3600) Molecular and Cellular Bioengineering (also BEE 360[3600])
Spring. 3 credits. Prerequisite: biochemistry course or A&EP 252 or permission of instructor.
For description, see BEE 360.

BME 401(4010) Biomedical Engineering Analysis of Metabolic and Structural Systems (also M&AE 466[4660])
Fall. 3 credits. Prerequisite: basic biology course work. Highly recommended: solid mechanics and fluid mechanics courses. Lec and lab. L. J. Bonassar and S. D. Archer.
Presents the quantitative biology of the renal, respiratory, cardiovascular, and musculoskeletal systems. Includes mathematical modeling of physiological processes involving mechanics and transport in solid and fluid organs.

BME 402(4020) Electrical and Chemical Physiology
Spring. 3 credits. Prerequisite: BME 301, 302, or 401 or biology background or permission of instructor. Lec and lab. D. Lipson and S. D. Archer.
Focuses on understanding how circulating agents and bioelectric activity comprises inter-organ and central nervous system communication, and control of the human body. Additional emphasis includes examining medical devices involved in the treatment of human disease.

BME 404(4040) Biomedical System Design (also ECE 402[4020])
Spring. 1–4 credits. Pre- or corequisites: at least one of ECE 425, 476, 453. J. C. Belina.
For description, see ECE 402.

BME 411(4110) Science and Technology Approaches to Problems in Human Health
Fall. 3 credits. Prerequisites: junior, senior, or graduate standing; sophomores by permission of instructor. C. B. Schaffer and M. G. Kaplitt.
Will provide an in-depth look at diseases that impact human health along with current scientific research and engineering that is aimed at addressing these problems. Faculty from the

Weill Cornell Medical College will discuss health problems they are unable to treat as well as they would like, then Cornell University and Weill faculty will discuss current research aimed at better understanding disease process, developing new treatment strategies, and improving patient outcomes. The course is particularly appropriate for students considering medical school or careers in biomedical science and engineering.

BME 442(4420) Instrumentation for Biology (also BIONB 442[4420])
Fall. 4 credits. B. R. Land.
For description, see BIONB 442.

[BME 463(4630) Neuromuscular Biomechanics (also M&AE 463[4630])]

BME 464(4640) Orthopaedic Tissue Mechanics (also M&AE 464[4640])
Spring. 3 credits. Prerequisites: ENGRD 202 and M&AE 325 or permission of instructor. Offered alternate years.
For description, see M&AE 464.

BME 481(4810) Biomedical Engineering (also CHEME 481[4810])
Spring. 3 credits. Prerequisite: CHEME 324 or equivalent or permission of instructor. W. L. Olbricht.
For description, see CHEME 481.

BME 490(4900) Independent Undergraduate Project in Biomedical Engineering
Fall, spring. Variable credit.
Research or projects by an individual or a small group of undergraduates.

BME 491(4910) Principles of Neurophysiology (also BIONB 491[4910])
Spring. 4 credits. Limited to 20 students. Prerequisite: BIONB 222 or written permission of instructor. S-U or letter grades for graduate students by permission of instructor. B. R. Johnson.
For description, see BIONB 491.

BME 501(5010) Bioengineering Seminar (also BEE 501[5010])
Fall, spring. 1 credit. Prerequisite: junior, senior, or graduate standing. D. Lipson and L. Bonassar.
Gives the engineer-in-training a BROAD overview of different aspects of biological and biomedical engineering including business, legal, and clinical issues. To give students a working knowledge of how abstracts are written and revised. Sessions may occasionally be held outside of scheduled times.

[BME 539(5390) Biomedical Materials and Devices for Human Body Repair (also FSAD 439[4390])
Spring. 2–3 credits. Prerequisites: junior or senior standing; college natural science requirement (chemistry or biology). Next offered 2008–2009. C. C. Chu.
For description, see FSAD 439.]

BME 550(5500) Product Engineering and Design in Biomedical Engineering
Fall. 3 credits. Prerequisite: graduate standing; requirement for M.Eng. students majoring in BME. D. Lipson.
A beginning to a cornerstone understanding of engineering, regulatory business, and individual issues for new medical product development. Student background and interests may be highly varied. To accommodate these varied perspectives, the initial focus of the class is on the engineering perspectives of design and development, enabling those undertaking projects (BME 591) to have timely exposure to key enabling concepts.

BME 562(5620) Biomineralization (also MS&E 562[5620])
Spring. 3 credits. L. Estroff.
For description, see MS&E 562.

BME 565(5650) Biomechanical Systems—Analysis and Design (also M&AE 565[5650])

BME 570(5700) Biophysical Methods (also BIONB/A&EP 470[4700])
Fall. 3 credits. Prerequisites: solid knowledge of basic physics and mathematics through sophomore level. Recommended: some knowledge of cellular biology. Letter grades only. M. Lindau.
For description, see A&EP 470.

BME 578(5780) Computer Analysis of Biomed Images (also ECE 578[5780])
Spring. 4 credits. Prerequisite: permission of instructor. A. P. Reeves.
For description, see ECE 578.

BME 581(5810) Soft Tissue Biomechanics
Fall. 3 credits. Prerequisites: graduate standing; seniors by permission of instructor. J. T. Butcher.
Introduces concepts of biomechanics applied to understanding the material behavior of soft tissues. Topics include finite strain, nonlinearities, constitutive frameworks, and experimental methodologies. Tissues to be modeled include tendons, blood vessels, heart valves, cartilage, and engineered tissues.

BME 585(5850) Current Practice in Tissue Engineering
Spring. 3 credits. Prerequisites: BME 301 or 401 (or BME 302 as corequisite). C. Fischbach-Teschl.
Covers fundamental biological principles and engineering concepts underlying the field of tissue engineering and describes specific strategies to engineer tissues for clinical use along with examples.

BME 591(5910) Design Project
Fall, spring. 3–6 credits. Requirement for M. Eng. students majoring in BME. Students encouraged to register for two semesters as continuing course. D. Lipson and staff.
Design and economic evaluation of a biomedical engineering device or therapeutic strategy. Team projects are encouraged.

BME 593(5930) Independent Design Project
Fall and spring. Variable credit. Prerequisite: graduate standing. D. Lipson and staff.
Graduate-level nonthesis research or studies on special projects in biomedical engineering.

BME 618(6180) Principles of Medical Imaging (also VTMED 618[6180])
Fall. 1–3 credits. Prerequisites: 3-credit enrollment requires functional knowledge and skills of linear algebra, calculus, Fourier transformation, and calculus-based physics. Y. Wang and N. Dykes.
One-credit version requires attendance the first five weeks of lectures on nonmathematical description of imaging principles and field trips to Cornell University Hospital for Animals (CUHA) to see imaging in clinical practice. Three-credit version requires attendance for the entire semester. The later part of the lectures focus on mathematical description of imaging principles. The formulations of spatial encoding and image contrasts are presented for all major medical imaging modalities: x-ray, CT, MR, SPECT/PET, US. The inverse problem between detected signal and image source will be discussed and the concepts of image resolution, SNR, and scan time will be illustrated analytically and quantitatively for all modalities.

BME 626(6260) Biomedical Optics, Imaging, and Spectroscopy
Spring. 3 credits. Prerequisites: introductory physics, calculus and biology. W. R. Zipfel.
Fundamentals of optical systems design, application and analysis concepts used in biological imaging and biomedical optics. The course covers the theory and application of light sources, lenses, mirrors, dispersion elements, optical fibers, detectors and tissue optics; optical systems analysis concepts such as resolution, optical transfer functions, deconvolution and interference, all in relation to biomedical microscopy, spectroscopy and bioanalytical techniques.

BME 631(6310) Engineering Principles for Drug Delivery (also CHEME 631[6310])
Fall. 3 credits. Prerequisites: graduate standing and background in organic and polymer chemistry or permission of instructor. D. A. Putnam.
Application of engineering design principles to problems in drug formulation and delivery. Specific topics include traditional drug formulation, mechanisms and kinetics of pharmaceutical stability, stimuli-sensitive systems, controlled release devices, prodrugs, targeted drug delivery, biomaterials, gene therapy, and governmental regulatory issues.

BME 641(6410) Biomedical Engineering Analysis of Proteins for Medicine
Spring. 3 credits. Prerequisites: graduate standing and background in biology and chemistry. M. Jin.
Protein engineering principles applied to developing molecules for biotherapeutics and biophysical studies. Course topics include general overview on biochemistry, molecular understanding of proteins in cell signaling, physiology, and pathophysiology, and reviews on modern instrumentations for biophysical studies of proteins. Includes hands-on experience with computers and algorithms for structure inspection and rational design of proteins for medicine.

BME 664(6640) Mechanics of Bone (also M&AE 664[6640])
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor. Offered alternate years.
For description, see M&AE 664.

[BME 665(6650) Principles of Tissue Engineering (also M&AE/MS&E 665[6650])
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor. (offered alternate years; next offered 2009–2010) L. Bonassar.
Covers introductory concepts in tissue engineering, including polymeric biomaterials used for scaffolds, mechanisms of cell-biomaterial interaction, biocompatibility and

foreign body response, cell engineering, and tissue biomechanics. This knowledge is applied to engineering of several body systems, including the musculoskeletal system, cardiovascular tissues, the nervous system, and artificial organs. These topics are discussed in the context of scale-up, manufacturing, and regulatory issues.]

BME 703(7030) Graduate Student Teaching Experience
Fall, spring. Variable credit. S-U or letter grades. Staff.
Guided individual experience in laboratory instruction and/or lectures/recitation instruction. Provides a preparatory teaching experience for graduate students considering an academic career.

BME 711(7110) Fundamentals of Biomedical Engineering Research I
Fall. 3 credits. Prerequisite: BME M.S./Ph.D. graduate students. W. R. Zipfel and staff.
First part of a two-semester sequence that introduces students to a variety of subjects in biomedical engineering including nanobiotechnology, biomechanics, systems and computational biology, biomaterials, tissue engineering, statistics, and experimental design. The course also covers associated subjects including professional development, ethics, writing a scientific paper, authorship issues, patents, technology transfer, conflicts of interest, and preparing a research proposal. The course is a combination of lectures and discussions, with students taking an active role in the instruction.

BME 712(7120) Fundamentals of Biomedical Engineering Research II
Spring. 3 credits. Prerequisite: BME 711 or permission of instructor. W. L. Olbricht and staff.
Continuation of BME 711.

BME 716(7160) Immersion Experience in Medical Research and Clinical Practice
Fall and spring. 6 credits. Prerequisite: Ph.D. students in BME. L. J. Bonassar and Y. Wang.
Seven-week immersion at Weill Medical College. Students participate in lectures, rounds, and seminars; observe surgeries; and solve medical problems presented by the staff.

BME 731(7310) Advanced Biomedical Engineering Analysis of Biological Systems
Fall. 3 credits. Prerequisite: graduate standing; priority given to M.S./Ph.D. and M.Eng. students majoring in BME. P. C. Doerschuk.
Covers the fundamentals of quantitative analysis of biological systems. Illustrates analytical methods applicable to a variety of biological systems, ranging from molecular to cellular to organ to application of whole-body systems.

BME 760(7600) Nucleic Acid Engineering (also BEE 760[7600])
Spring. 2 credits. Prerequisite: graduate standing; BEE 360 or permission of instructor. D. Luo.
For description, see BEE 760.

BME 790(7900) Biomedical Engineering Seminar
Fall, spring. 1 credit. Prerequisite: graduate standing. M. L. Shuler.
Research-based seminars. May meet with other seminar series as appropriate.

BME 890(8999) M.S. Thesis Research
Fall, spring. Variable credit.
Thesis research for the M.S. degree in BME.

BME 990(9999) Ph.D. Thesis Research
Fall, spring. Variable credit.
Thesis research for the Ph.D. degree in BME.

CHEMICAL AND BIOMOLECULAR ENGINEERING

P. Clancy, director; A. B. Anton, L. A. Archer, A. M. Center, C. Cohen, S. Daniel, M. P. DeLisa, T. M. Duncan, J. R. Engstrom, F. A. Escobedo, T. Hanrath, Y. L. Joo, D. L. Koch, W. L. Olbricht, D. A. Putnam, M. L. Shuler, P. H. Steen, A. D. Stroock, J. D. Varner

CHEME 112(1120) Introduction to Chemical Engineering (also ENGRI 112[1120])
Fall. 3 credits. Prerequisite: freshman standing. T. M. Duncan.
Course in the Introduction to Engineering series. For description, see ENGRI 112.

CHEME 219(2190) Mass and Energy Balances (also ENGRD 219[2190])
Fall. 3 credits. Corequisite: physical chemistry course or permission of instructor. S. Daniel.
For description, see ENGRD 219.

CHEME 288(2880) Biomolecular Engineering: Fundamentals and Applications
Spring. 3 credits. Prerequisite: ENGRD 219 Mass and Energy Balances. Staff.
A basic introduction to modern biology including aspects of biochemistry, molecular and cellular biology intended for students with no significant background in this area. An emphasis on practical applications of this knowledge in a variety of settings including the production of industrial enzymes, pharmaceuticals, and biologics.

CHEME 301(3010) Nonresident Lectures
Spring. 1 credit. P. Clancy.
Lecturers from industry and from selected departments of the university provide information to assist students in their post-graduate plans.

CHEME 313(3130) Chemical Engineering Thermodynamics
Fall. 3 credits. Prerequisite: physical chemistry II. T. Hanrath.
Studies the first and second laws and their consequences for chemical systems. Covers thermodynamic properties of pure fluids, solids, and mixtures; phase and chemical reaction equilibrium; heat effects in batch and flow processes; and power cycles and refrigeration.

CHEME 323(3230) Fluid Mechanics
Spring. 3 credits. Prerequisites: CHEME 219 and engineering mathematics sequence. L. A. Archer.
Fundamentals of fluid mechanics. Macroscopic and microscopic balances. Applications to problems involving viscous flow.

CHEME 324(3240) Heat and Mass Transfer
Fall. 3 credits. Prerequisite: CHEME 323. A. D. Stroock.
Fundamentals of heat and mass transfer. Macroscopic and microscopic balances. Applications to problems involving conduction, convection, and diffusion.

CHEME 332(3320) Analysis of Separation Processes
Spring. 3 credits. Prerequisites: CHEME 313 and 324. A. B. Anton.
Covers the analysis of separation processes involving phase equilibria and mass transfer. Topics include phase equilibria; equilibrium-based separations; rate-based separation processes (membrane separations, sorption operations); introduction to bioseparations and process simulators; choosing a separation option; and the design and synthesis of separation processes.

CHEME 372(3720) Introduction to Process Dynamics and Control
Spring. 2 credits. Prerequisites: CHEME 313 and 323. Staff.
Modeling and analysis of the dynamics of chemical processes, Laplace transforms, block diagrams, feedback control systems, and stability analysis.

CHEME 390(3900) Reaction Kinetics and Reactor Design
Spring. 3 credits. Prerequisites: CHEME 313 and 323. J. R. Engstrom.
Study of chemical reaction kinetics and principles of reactor design for chemical processes.

CHEME 401(4010) Molecular Principles of Biomedical Engineering (also BME 301[3010])
Fall. 3 credits. Prerequisite: BIO G 110 or BIOBM 330. M. Jin.
For description, see BME 301.

CHEME 402(4020) Cellular Principles of Biomedical Engineering (also BME 302[3020])
Spring. 3 credits. D. A. Putnam.
For description, see BME 302.

CHEME 424(4240) Physics of Micro- and Nanoscale Fluid Mechanics and Heat Transfer
Spring. 3 credits. Prerequisites: undergraduate fluid or continuum mechanics (e.g., M&AE 323, CHEME 323, A&EP 434) or permission of instructor. B. L. Kirby.
For description, see M&AE 524.

CHEME 432(4320) Chemical Engineering Laboratory
Fall. 4 credits. Prerequisites: CHEME 323, 324, 332, and 390. A. M. Center and staff.
Laboratory experiments in fluid dynamics, heat and mass transfer, separations, other operations. Correlation and interpretation of data. Technical report writing.

CHEME 462(4620) Chemical Process Design
Spring. 4 credits. Prerequisite: CHEME 432. A. M. Center and staff.
Students prepare a full-scale feasibility study of a chemical process including product supply and demand forecasts, process design including reaction system design, separations scheme development, heat integration via application of pinch technology, and economic analysis of the process. Students develop presentation and teamwork skills through weekly presentations.

CHEME 470(4700) Process Control Strategies
Spring. 3 credits. A. M. Center.

Introduction to how control concepts are represented, control valve sizing and selection, process control strategies, dynamic response of process systems as it relates to control loop tuning, statistical process control, advanced process control methods both for chemical and biological processes and programmable logic controllers and distributed control systems.

CHEME 472(4720) Feedback Control Systems (also ECE 472[4720], M&AE 478[4780])

Fall. 4 credits. Prerequisites: CHEME 372, ECE 220, M&AE 326, or permission of instructor.

For description, see M&AE 478.

CHEME 480(4800) Chemical Processing of Electronic Materials

Spring. 3 credits. A. B. Anton.

Introduction to chemical processing of semiconductor materials for the manufacture of microelectronic devices, with specific emphasis on thermodynamics, transport phenomena, and kinetics. Topics include semiconductor properties and behavior, microelectronic device operation, thermochemistry of deposition and etching reactions, vacuum transport, plasmas, PVD, oxidation, diffusion, CVD, and statistical process control.

CHEME 481(4810) Biomedical Engineering (also BME 481[4810])

Spring. 3 credits. Prerequisite: CHEME 324 or equivalent or permission of instructor. W. L. Olbricht.

Special topics in biomedical engineering, including cell separations, blood flow, design of artificial devices and artificial organs, biomaterials, image analysis, biological transport phenomena, pharmacokinetics and drug delivery, tissue engineering, and analysis of physiological processes such as adhesion, mobility, secretion, signaling, and growth.

CHEME 484(4840) Microchemical and Microfluidic Systems

Fall. 3 credits. Prerequisite: CHEME 390 or permission of instructor. J. R. Engstrom.

Principles of chemical kinetics, thermodynamics, and transport phenomena applied to microchemical and microfluidic systems. Applications in distributed chemical production, portable power, micromixing, separations, and chemical and biological sensing and analysis. Fabrication approaches (contrasted with microelectronics), transport phenomena at small dimensions, modeling challenges, system integration, case studies.

CHEME 490(4900) Undergraduate Projects in Chemical Engineering

Fall, spring. Variable credit.

Research or studies on special problems in chemical engineering.

CHEME 499(4990) Senior Seminar

Fall, spring. 1 credit. Prerequisite: CHEME seniors. Staff.

Students attend seminars of their selection and write one-page summaries. Eligible seminars include all listings at "Colloquia and Seminars in Physics and Related Fields" which includes the weekly seminars in, for example, Chemical and Biomolecular Engineering, Chemistry and Chemical Biology, Earth and Atmospheric Sciences, History and Ethics of Engineering, and Materials Science and Engineering.

CHEME 520(5200) An Overview of Chemical Processing

Fall, spring. 1–6 credits; 1 credit per sec.

Spring, first third of semester. 1 credit. Prerequisite: nonchemical engineers. T. M. Duncan.

Introduction to chemical engineering design and analysis-mathematical modeling, graphical methods and dynamic scaling.

CHEME 521(5201) Introduction to Biomedical Engineering (module)

Spring, first third of semester. 1 credit. W. L. Olbricht.

Meets concurrently with CHEME 481.

CHEME 522(5202) Introduction to Electronic Materials Processing (module)

Spring, first third of semester. 1 credit. A. B. Anton.

Meets concurrently with CHEME 480.

CHEME 523(5203) Introduction to Polymer Processing (module)

Spring, second third of semester. 1 credit. L. A. Archer.

Overview and simple quantitative analyses of several plastic processes with an emphasis on the role of rheology in polymer processing.

CHEME 524(5204) Turbomachinery Applications (module)

Fall, last third of semester. 1 credit. A. M. Center.

Introduction to pumps, compressors, steam turbines and gas turbines. How they are specified and selected for services in the chemical process industries.

CHEME 525(5205) Chemical Engineering Tools and Equipment (module)

Spring, first third of semester. 1 credit. A. M. Center.

Introduces the hardware used in chemical engineering processes and a discussion of how these mechanical devices are configured to meet their process objectives. Also includes an introduction to the evaluation techniques and trouble-shooting methods frequently used by chemical engineers.

CHEME 526(5206) Hydrocarbon Resource Exploration and Development (module)

Fall, second third of semester. 1 credit. A.M. Center

An examination of hydrocarbon resource formation, geology, exploration, drilling, development, and initial processing prior to shipment.

CHEME 527(5207) Introduction to Petroleum Refining (module)

Fall, second third of semester. 1 credit. A. M. Center.

Covers the petroleum refining industry including crude oil evaluation, fuel quality, refining processes, refinery configurations, and refinery economics.

CHEME 528(5208) Renewable Resources from Agriculture-Sugarcane as a Feedstock (module)

Fall, last third of semester. 1 credit. A. M. Center.

Maximizing the value of a renewable resource by control of inputs and final product use.

CHEME 543(5430) Bioprocess Engineering

Fall. 3 credits. Prerequisite: CHEME 390 or permission of instructor. No prior background in biological sciences required. Staff.

Discusses principles involved in using microorganisms, tissue cultures, and enzymes for processing. Primary emphasis is on production of biopharmaceuticals, but biological waste treatment and medical systems are also considered.

CHEME 564(5640) Design of Chemical Reactors

Spring. 3 credits. Prerequisite: CHEME 390 or equivalent. D. L. Koch.

Design, scale-up, and optimization of chemical reactors with allowance for heat and mass transfer and non-ideal flow patterns. Homework problems feature analysis of published data for gas-solid, gas-liquid, and three-phase reaction systems.

CHEME 565(5650) Design Project

Fall, spring. 3 or 6 credits. Requirement for Chemical Engineering M.Eng. students.

Design study and economic evaluation of a chemical processing facility, alternative methods of manufacture, raw-material preparation, food processing, waste disposal, or some other aspect of chemical processing.

CHEME 572(5720) Managing New Business Development

Fall. 3 credits. Prerequisites: graduate standing or permission of instructor. A. M. Center.

Case study approach introducing the typical fundamental factors driving a business venture, examines how to develop implementation strategies for the venture, and teaches the project management skills necessary to successfully implement the venture.

CHEME 590(5999) Special Projects in Chemical Engineering

Fall, spring. Variable credit. Prerequisite: graduate standing.

Nonthesis research or studies on special problems in chemical engineering.

CHEME 631(6310) Engineering Principles for Drug Delivery (also BME 631[6310])

Fall. 3 credits. Prerequisite: graduate standing or permission of instructor. D. A. Putnam.

For description, see BME 631.

CHEME 640(6400) Polymeric Materials

Fall. 3 credits. C. Cohen.

Covers chemistry and physics of the formation and characterization of polymers; principles of fabrication.

CHEME 644(6440) Aerosols and Colloids

Fall. 3 credits. D. L. Koch.

Dynamics of micro- and nano-particles, which contain many molecules but are small enough that molecular effects are important. Topics include the formation and growth of particles; their transport, theological and phase behaviors; and their role in technologies including paints, foods, health-care products, drug delivery, composite materials and air pollution control.

CHEME 661(6610) Air Pollution Control

Spring. 3 credits. P. H. Steen.

Covers origin of air pollutants, U.S. emission standards, dispersion equations; design of equipment for removal of particulate and gaseous pollutants formed in combustion and chemical processing.

CHEME 664(6640) Energy Economics
Fall. 3 credits. A. J. Hunter.
Supply and demand for energy by sectors and regions. Operating systems and costs. Economic drivers used in simulating energy systems and consumption factors. Supply/demand projections. Interplay between energy, environment, politics, economics, and sustainability.

CHEME 665(6650) Energy Engineering
Spring. 3 credits. A. J. Hunter.
Applying thermodynamic concepts to large energy systems. Future energy scenarios. Project teams tasked with simulating complex energy systems and cost-benefit analysis.

CHEME 675(6750) Synthetic Polymer Chemistry (also MS&E 622[6220], CHEM 671[6710])
Spring. 4 credits. Prerequisites: CHEM 359–360 or equivalent or permission of instructor.
For description, see CHEM 671.

CHEME 711(7110) Advanced Chemical Engineering Thermodynamics
Fall. 3 credits. Prerequisite: CHEM 389–390 and CHEME 313 or equivalent. F. A. Escobedo.
Molecular thermodynamics of gases, lattices, and liquids, including special applications to problems in chemical engineering.

CHEME 713(7130) Chemical Kinetics and Transport
Spring. 5 credits. Prerequisite: CHEME 390 or equivalent. C. Cohen and A. D. Stroock.
Topics include microscopic and macroscopic viewpoints; connections between phenomenological chemical kinetics and molecular reaction dynamics; reaction cross sections, potential energy surfaces, and dynamics of biomolecular collisions; molecular beam scattering; transition state theory. Unimolecular reaction dynamics; complex chemically reacting systems: reactor stability, multiple steady states, oscillations, and bifurcation; reactions in heterogeneous media; and free-radical mechanisms in combustion and pyrolysis.

CHEME 731(7310) Advanced Fluid Mechanics and Heat Transfer
Fall. 3 credits. Prerequisites: CHEME 323–324 or equivalent. Y. L. Joo.
Topics include derivation of conservation equations; conductive heat transfer; low Reynolds number fluid dynamics; lubrication theory; inviscid fluid dynamics; boundary layer theory; forced convection; and introduction to non-Newtonian fluid mechanics (polymeric liquids and suspensions), microfluidics, stability analysis, and turbulent flow.

CHEME 741(7410) Selected Topics in Biochemical Engineering
Fall, spring. 1 credit; may be repeated for credit. Prerequisite: permission of instructor. D. A. Putnam and M. P. DeLisa.
Discussion of current topics and research in biochemical engineering for graduate students.

[CHEME 745(7450) Physical Polymer Science I
Fall. 3 credits. Corequisite: CHEME 711 or equivalent. Offered alternate years; next offered 2008–2009. L. A. Archer.
Thermodynamic properties of solutions from both classical and scaling approaches. Characterization techniques of dilute solutions. Rubber elasticity; mechanical and thermodynamic properties of gels; polymer melts.]

CHEME 751(7510) Mathematical Methods of Chemical Engineering Analysis
Fall. 4 credits. Staff.
Application of advanced mathematical techniques to chemical engineering analysis. Mathematical modeling, scaling, regular and singular perturbations, multiple scales, asymptotic analysis, linear and nonlinear ordinary and partial differential equations, statistics, data analysis, and curve fitting.

[CHEME 753(7530) Analysis of Nonlinear Systems: Stability, Bifurcation, and Continuation
Fall. 3 credits. Prerequisite: CHEME 751 or equivalent. Offered alternate years; next offered 2008–2009. P. H. Steen.]

CHEME 790(7900) Seminar
Fall, spring. 1 credit each semester. Requirement for all graduate students in field of chemical and biomolecular engineering.
General chemical engineering seminar.

CHEME 792(7920) Principles and Practices of Graduate Research
Fall. 1 credit. M. P. DeLisa and A. D. Stroock.
A colloquium/discussion group series for first-year graduate students. Topics include the culture and responsibilities of graduate research and the professional community; the mechanics of conducting research (experimental design, data analysis, serendipity in research, avoiding self-deception), documenting research (lab notebooks, computer files) and reporting research (writing a technical paper and oral presentations).

CHEME 890(8999) Thesis Research
Fall, spring. Variable credit.
Thesis research for the M.S. degree in chemical engineering.

CHEME 990(9999) Thesis Research
Fall, spring. Variable credit.
Thesis research for the Ph.D. degree in chemical engineering.

CIVIL AND ENVIRONMENTAL ENGINEERING

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Courses in the School of Civil and Environmental Engineering are offered in three broad mission areas: Civil Infrastructure, Environment, and Engineering Systems and Management. Each area has several areas of specialization. The following are the course numbers and titles listed by specialization within each mission area. Some courses are listed in two or more mission areas because the course content is relevant to multiple areas. The school also offers a number of general courses that are not unique to one mission area. Full course descriptions follow in the subsequent section and are listed in numerical order.

General

CEE 113 Sustainability for Appledore Island (also ENGRI 113) (s,3)

CEE 116 Modern Structures (also ENGRI 116) (f,3)

CEE 320 Engineering Computation (formerly CEE/ENGRD 241) (also ENGRD 320) s,3)

CEE 304 Uncertainty Analysis in Engineering (f,4)

CEE 308 Introduction to CADD (f,s,1)

CEE 309 Special Topics in Civil and Environmental Engineering (f,s,var.)

CEE 323 Engineering Economics and Management (also ENGRG 323) (s,su,3)

CEE 400 Senior Honors Thesis (f,s,var.)

CEE 401 Undergraduate Engineering Teaching in CEE (f,s,var.)

Civil Infrastructure

See also: CEE 116, 320, 304, 308, 503, and 595

Geotechnical Engineering

CEE 341 Introduction to Geotechnical Engineering (s,4)

CEE 440 Foundation Engineering (f,3)

CEE 441 Retaining Structures and Slopes (s,3)

CEE 444 Environmental Site and Remediation Engineering (s,3)

CEE 501/502 Design Project in Geotech/Structures (f,s,3)

CEE 602 Seminar—Civil Infrastructure (f,s,1)

CEE 640 Foundation Engineering (f,3)

CEE 641 Retaining Structures and Slopes (s,3)

CEE 644 Environmental Site and Remediation Engineering (s,3)

CEE 649 Special Topics in Geotechnical Engineering (f,s,var.)

CEE 740 Engineering Behavior of Soils (f,3)

CEE 741 Rock Engineering (f,3)

CEE 744 Advanced Foundation Engineering (s,2)

CEE 745 Soil Dynamics (s,3)

CEE 746 Embankment Dam Engineering (s,2)

CEE 749 Research in Geotechnical Engineering (f,s,var.)

CEE 840 Thesis—Geotechnical Engineering (f,s,var.)

Structural Engineering

CEE 116 Modern Structures (f,3)

CEE 371 Structural Modeling and Behavior (s,4)

CEE 372 Intermediate Solid Mechanics (f,4)

CEE 471 Fundamentals of Structural Mechanics (f,4)

CEE 472 Introduction to the Finite Element Method (f,3)

CEE 473 Design of Concrete Structures (s,4)

CEE 474 Design of Steel Structures (s,4)

CEE 475 Concrete Materials and Construction (s,3)

CEE 477 Introduction to Composite Materials (f,3)

CEE 478 Structural Dynamics and Earthquake Engineering (s,3)

CEE 481 LRFD-Based Engineering of Wood Structures (s,3)

CEE 501/502 Design Project in Structural Engineering (f,s,3)

CEE 602 Seminar—Civil Infrastructure (f,s,1)

CEE 671 Fundamentals of Structural Mechanics (f,3)

CEE 672 Introduction to the Finite Element Method (f,3)

CEE 673 Design of Concrete Structures (s,4)

CEE 675 Concrete Materials and Construction (s,3)

CEE 676 Advanced Composite Materials (s,4)

CEE 677 Engineering Analysis (f,3)

CEE 678 Structural Dynamics and Earthquake Engineering (s,3)

CEE 679 Evaluation and Failure of Structures (s,3)

CEE 697 Special Topics in Structural Engineering (f,s,var.)

CEE 770 Engineering Fracture Mechanics (f,3)

CEE 771 Stochastic Mechanics in Science and Engineering (f,3)

CEE 772 Random Vibration (f,3)

CEE 773 Structural Reliability (f,3)

CEE 774 Advanced Structural Concrete (f,3)

CEE 775 Nonlinear Finite Element Analysis (s,3)

CEE 776 Advanced Topics in Stability (s,3)

CEE 777 Computational Solids and Structural Mechanics (s,4.)

CEE 779 Advanced Behavior of Metal Structures (f,4)

CEE 781 National Disaster Risk Assessment and Management (s,3)

CEE 783 Civil and Environmental Engineering Materials Project (f,s,var.)

CEE 785 Research in Structural Engineering (f,s,var.)

CEE 786 Special Topics in Structural Engineering (f,s,var.)

CEE 880 Thesis—Structural Engineering (f,s,var.)

Environment

See also CEE 113, 320, 304, and 492

Environmental Engineering

CEE 113 Sustainability Design for Appledore Island (s,3)

CEE 255 AguaClara: Sustainable Water Supply Project (f,s,var.)

CEE 351 Environmental Quality Engineering (s,3)

CEE 451 Microbiology for Environmental Engineering (f,3)

CEE 452 Water Supply Engineering (s,3)

CEE 453 Laboratory Research in Environmental Engineering (s,3)

CEE 454 Sustainable Small-Scale Water Supplies (f,3)

CEE 455 AguaClara: Sustainable Water Supply Project (f,s,3)

CEE 501/502 Design Project in Environmental Engineering (f,s,3)

CEE 601 Seminar—Water Resources and Environmental Engineering (f,1)

CEE 653 Water Chemistry for Environmental Engineering (f,3)

CEE 654 Aquatic Chemistry (s,3)

CEE 655 Transport, Mixing, and Transformation in the Environment (f,3)

CEE 656 Physical/Chemical Process (f,3)

CEE 657 Biological Processes (s,3)

CEE 658 Biodegradation and Biocatalysis (s,3)

CEE 659 Seminar—Environmental Quality Engineering (s,1)

CEE 736 Turbulences and Turbulent Mixing in Environmental Stratified Flows (s,3)

CEE 750 Research in Environmental Engineering (f,s,var.)

CEE 759 Special Topics in Environmental Engineering (f,s,var.)

CEE 850 Thesis—Environmental Engineering (f,s,var.)

Environmental Systems

See Engineering Systems and Management mission areas for a listing of courses in Environmental and Public Systems.

Environmental Fluid Mechanics and Hydrology

CEE 331 Fluid Mechanics (f,su,4)

CEE 332 Hydraulic Engineering (s,4)

CEE 432 Hydrology (s,3)

CEE 435 Coastal Engineering (s,3)

CEE 436 Case Studies in Environmental Fluid Mechanics (s,4)

CEE 437 Experimental Methods in Fluid Dynamics (s,3)

CEE 601 Seminar—Water Resources and Environmental Engineering (f,1)

CEE 609 Advanced Numerical Methods for Engineers (f,3)

CEE 630 Computational Fluid Dynamics and Environmental Flows (s,3)

CEE 631 Computational Simulation of Flow and Transport in the Environment (s,3)

CEE 632 Hydrology (s,3)

CEE 633 Flow in Porous Media and Groundwater (f,3)

CEE 634 Boundary Layer Meteorology (f,3)

CEE 635 Small and Finite Amplitude Water Waves (s,3)

CEE 636 Environmental Fluid Mechanics (s,3)

CEE 637 Experimental Methods in Fluid Dynamics (s,4)

CEE 638 Seminar—Hydraulics (s,1)

CEE 639 Special Topics in Hydraulics (f,s,var.)

CEE 655 Transport, Mixing, and Transformation in the Environment (f,3)

CEE 735 Research in Hydraulics (f,s,var.)

CEE 830 Thesis—Fluid Mechanics and Hydrology (f,s,var.)

Engineering Systems and Management

See also CEE 304.

Engineering Management

CEE 492 Engineers for a Sustainable World (f,3)

CEE 590 Project Management (f,s,4)

CEE 591/592 Engineering Management Project (f,s,3)

CEE 593 Engineering Management Methods (f,3)

CEE 594 Economic Methods for Engineering and Management (f,4)

CEE 595 Construction Planning and Operations (f,3)

CEE 596 Management Issues in Forensic Engineering (f,3)

CEE 597 Risk Analysis and Management (s,3)

CEE 690 Creativity, Innovation, and Leadership (s,3)

CEE 692 Special Topics in Engineering Management (f,s,var.)

Environmental and Public Systems

CEE 323 Engineering Economics and Management (also ENGRG 323) (s,su,3)

CEE 465 Environment/Energy and Transportation Planning and Management (s,3)

CEE 501/502 Design Project in Environmental or Water Resource Systems (f,s,3)

CEE 597 Risk Analysis and Management (s,3)

CEE 620 Water Resources Systems Engineering (s,3)

CEE 621 Stochastic Hydrology (s,3)

CEE 623 Environmental Quality Systems Engineering (f,3)

CEE 628 Seminar—Environmental and Water Resources Systems Analysis (s,1)

CEE 636 Environmental Fluid Mechanics (s,4)

CEE 665 Environment/Energy and Transportation Planning and Management (s,3)

CEE 693 Public Systems Modeling (f,4)

CEE 722 Environmental and Water Resources Systems Analysis Research (f,s,var.)

CEE 729 Special Topics in Environmental and Water Resources Systems Analysis (f,s,var.)

CEE 820 Thesis—Environmental and Water Resources Systems (f,s,var.)

Remote Sensing

CEE 411 Remote Sensing: Resource Inventory Methods (also CSS 411) (s,3)

CEE 610 Remote Sensing Fundamentals (also CSS 660) (f,3)

CEE 615 Digital Image Processing (s,3)

CEE 617 Special Topics—Remote Sensing (f,s,var.)

CEE 710 Research—Remote Sensing (f,s,var.)

CEE 810 Thesis—Remote Sensing (f,s,var.)

Systems Engineering

CEE 406 Civil Infrastructure Systems (f,3)

CEE 504 Applied Systems Engineering (also M&AE 591, ECE/OR&IE 512, SYSEN 510, CS 504) (f,3)

CEE 505 Systems Architecture, Behavior, and Optimization (also M&AE 592, ECE/OR&IE 513, SYSEN 520, CS 505) (s,3)

CEE 509 Heuristic Methods for Optimization (also CS 574, CIS 572, OR&IE 533) (f,3–4)

CEE 603 Seminar—Engineering Systems and Management (f,s,1)

CEE 606 Civil Infrastructure Systems (f,3)

CEE 693 Public Sytems Modeling (f,4)

Transportation

CEE 361 Introduction to Transportation Engineering (s,su,3)

CEE 461 Urban Transportation Planning and Modeling (s,3)

CEE 463 Transportation and Information Technology (f,3)

CEE 464 Transportation Systems Design (s,3)

CEE 465 Environment/Energy and Transportation Planning and Management (s,3)

CEE 501/502 Design Project in Transportation Engineering (f,s,3)

CEE 661 Urban Transportation Planning and Modeling (s,3)

CEE 662 Urban Transportation Network and Design and Analysis (f,3)

CEE 663 Network Flows and Algorithms (s,3)

CEE 665 Environment/Energy and Transportation Planning and Management (s,3)

CEE 668 Seminar—Transportation (f,s,1)

CEE 762 Practicum in Modeling Transportation Systems (f,3)

CEE 764 Special Topics in Transportation (f,s,var.)

CEE 860 Thesis—Transportation Engineering (f,s,var.)

CEE 113(1130) Sustainability Design for Appledore Island (also ENGRI 113[1130])

Spring. 3 credits. Students must register under ENGRI 113. J. J. Bisogni.

The course utilizes a unique environment, Appledore island, as an example of how sustainability is addressed in the design of basic components of the built environment; energy, water supply and waste treatment. Students will present preliminary designs of sustainable systems to the engineering staff of Appledore Island.

CEE 116(1160) Modern Structures (also ENGRI 116[1160])

Fall. 3 credits. Students must register under ENGRI 116. A. Ingraffea.

Course in Introduction to Engineering series. For description, see ENGRI 116.

CEE 255(2550) AguaClara: Sustainable Water Supply Project

Fall, spring. 1–3 credits. Meets with CEE 455. M. L. Weber-Shirk.

For description, see CEE 455.

CEE 304(3040) Uncertainty Analysis in Engineering

Fall. 4 credits. CEE Engineering co-op students may substitute summer ENGRD 270. Prerequisite: first-year calculus. J. R. Stedinger.

Introduction to probability theory and statistical techniques, with examples from civil, environmental, biological, and related disciplines. Covers data presentation, commonly used probability distributions describing natural phenomena and material properties, parameter estimation, confidence intervals, hypothesis testing, simple linear regression, and nonparametric statistics. Examples include structural reliability, windspeed/flood distributions, pollutant concentrations, and models of vehicle arrivals.

CEE 308(3080) Introduction to CADD

Fall, spring. 1 credit. Prerequisites: attendance at a first meeting of one section; permission of instructor. No pre-enrollment allowed. Priority given to engineering students. Course begins first Mon. of Fall and second Mon. of Spring. Staff.

Students learn to employ computer-aided design and drafting (CADD) to construct 2D drawings and 3D models using a variety of AutoCAD techniques. VIZ, an alternative software tool for 3D modeling and 3D visualization, is also introduced. Course meets in ACCEL (second floor of the Engineering Library in Carpenter Hall) so that each student can participate on an individual computer. Grades are based on attendance, weekly exercises completed in class, and a semester project due the last Friday of classes.

CEE 309(3090) Special Topics in Civil and Environmental Engineering

Fall, spring. 1–6 credits. Staff.

Supervised study by individuals or groups of upper-division students on an undergraduate research project or on specialized topics not covered in regular courses.

CEE 320(3200) Engineering Computation (also ENGRD 320[3200]) (formerly ENGRD/CEE 241)

Spring. 3 credits. Students must register under ENGRD 320. C. Shoemaker.

For description, see ENGRD 320.

CEE 323(3230) Engineering Economics and Management (also ENGRG 323[3230])

Spring; usually offered in summer for Engineering Co-op Program. 3 credits. Primarily for juniors and seniors. D. P. Loucks.

For description, see ENGRG 323.

CEE 331(3310) Fluid Mechanics

Fall; usually offered in summer for Engineering Co-op Program. 4 credits. Pre- or corequisite: ENGRD 202. E. A. Cowen.

Covers hydrostatics, the basic equations of incompressible fluid flow, potential flow and dynamic pressure forces, viscous flow and shear forces, steady pipe flow, turbulence, dimensional analysis, laminar and turbulence boundary layer, flows around obstacles, and open-channel flow. Includes small-group laboratory assignments.

[CEE 332(3320) Hydraulic Engineering

Spring. 4 credits. Prerequisite: CEE 331. Next offered 2008–2009. P. L.-F. Liu.

Application of fluid-mechanical principles to problems of engineering practice and design: hydraulic machinery, open-channels, and river engineering. Lectures supplemented by laboratory work and a design project.]

CEE 341(3410) Introduction to Geotechnical Engineering

Spring. 4 credits. Prerequisites: ENGRD 202, CEE 331 (or equivalent), or permission of instructor. Letter grades only. H. E. Stewart.

Fundamentals of geotechnical engineering. Topics include origins and descriptions of soil and rock as engineering materials, subsurface exploration methods, principles of effective stresses, stress distribution and ground settlements from surface loads, steady-state and time-dependent subsurface fluid flow, soil strength and failure criteria, geoenvironmental applications, and introduction to hazardous waste containment systems.

CEE 351(3510) Environmental Quality Engineering

Spring. 3 credits. L. W. Lion.

Introduction to engineering aspects of environmental quality control. Quality parameters, criteria, and standards for water and wastewater. Elementary analysis pertaining to the modeling of pollutant reactions in natural systems, and introduction to design of unit processes for wastewater treatment.

CEE 361(3610) Introduction to Transportation Engineering

Spring; usually offered in summer for Engineering Co-op Program. 3 credits. A. H. Meyburg and J. Mbwana.

Introduction technological, economic, and social aspects of transportation. Emphasizes design and functioning of transportation systems and their components. Covers supply-demand interactions; system planning, design, and management; traffic flow, intersection control and network analysis; institutional and energy issues; and environmental impacts.

CEE 371(3710) Structural Modeling and Behavior

Spring. 4 credits. Prerequisite: ENGRD 202. Corequisite: MATH 294. A. R. Ingraffea.

Introduction to the structural engineering enterprise including aspects of design, loads, behavior, form, modeling, mechanics, materials, analysis, and construction/ manufacturing. Case studies involve different scales and various materials. Topics include analytical and finite-element computational modeling of structural systems, including cables, arches, trusses, beams, frames, and 2-D continua; deflections, strains, and stresses of structural members, systems, and 2-D continua by analytical and work/energy methods, with a focus on linear elastic behavior; the foundations of matrix structural analysis; and the application of finite-element software.

CEE 372(3720) Intermediate Solid Mechanics

Fall. 4 credits. Prerequisites: MATH 294, CEE 371. W. Aquino.

The course presents concepts related to inelastic and nonlinear behavior of engineering materials and structures, the concept of continuum, limit and plastic analysis, and fracture. The course will be a synergy of mathematical modeling, computer simulations, and physical experimentation.

CEE 400(4000) Senior Honors Thesis

Fall, spring. 1–6 credits. For students admitted to CEE Honors Program. Staff.

Supervised research, study, and/or project work resulting in a written report or honors thesis.

CEE 401(4010) Undergraduate Engineering Teaching in CEE
Fall, spring. 1–3 credits. Prerequisite: permission of instructor. Staff.
Methods of instruction developed through discussions with faculty and by assisting with the instruction of undergraduates under the supervision of faculty.

CEE 406(4060) Civil Infrastructure Systems
Fall. 3 credits. Prerequisites: probability and statistics (CEE 304 or equivalent) and engineering economics (CEE 323 or equivalent) course. Letter or S-U grades. F. Vanek.
Introduction to the framing and solution of civil infrastructure problems using a systems engineering approach. Systems tools, such as optimization, life-cycle cost analysis, decision analysis, simulation, and risk analysis are examined through case studies related to civil infrastructure.

CEE 411(4110) Remote Sensing: Resource Inventory Methods (also CSS 411[4110])
Spring. 3 credits. Prerequisite: permission of instructor. A. Lembo.
For description, see CSS 411.

CEE 432(4320) Hydrology
Spring. 3 credits. Prerequisite: CEE 331. Intended for undergraduates. Lec concurrent with CEE 632. W. H. Brutsaert.
Introduction to hydrology as a description of the water cycle and the role of water in the natural environment, and other issues for environmental engineers. See description for CEE 632.

[CEE 435(4350) Coastal Engineering
Spring. 4 credits. Prerequisite: CEE 331. Taught based on demand; contact professor if interested in course. P. L-F. Liu.
Covers the following topics: review of hydrodynamics; small-amplitude wave theory; wave statistics; wave-structure interactions; coastal processes.]

[CEE 436(4360) Case Studies in Environmental Fluid Mechanics
Spring. 4 credits. Prerequisite: CEE 331 or equivalent. Next offered 2008–2009. E. A. Cowen.
An introduction to fundamental fluid mechanics and transport processes of the environment through laboratory—and field—based studies (Cayuga Lake and Fall, Six-Mile, and Cascadilla Creeks) and case studies. Topics include surface and internal wave dynamics, sediment and nutrient/contaminant transport, and interfacial transfer. Lectures are based on a laboratory/field projects. Course includes a design project.]

CEE 437(4370) Experimental Methods in Fluid Dynamics
Spring. 3 credits. Pre- or corequisites: CEE 331 or equivalent and CEE 304 or equivalent. E. A. Cowen.
Same as CEE 637 but no project required. For description, see CEE 637.

CEE 440(4400) Foundation Engineering
Fall. 3 credits. Prerequisite: CEE 341. T. D. O'Rourke.
Covers soil exploration, sampling, and in-situ testing techniques; bearing capacity, stress distribution, and settlement; design of shallow and deep foundations; compaction and site preparation; and seepage and dewatering of foundation excavations.

CEE 441(4410) Retaining Structures and Slopes
Spring. 3 credits. Prerequisite: CEE 341. T. D. O'Rourke
Covers earth pressure theories; design of rigid, flexible, braced, tied-back, slurry wall, soil nailing, and reinforced soil structures; stability of excavation, cut, and natural slopes; and design problems stressing application of course material under field conditions of engineering practice.

[CEE 444(4440) Environmental Site and Remediation Engineering
Spring. 3 credits. Prerequisite: CEE 341. Next offered 2008–2009. T. D. O'Rourke.
Covers the principles of hydrogeology, contaminant migration, and remediation technologies related to geotechnical and environmental engineering. Emphasizes environmental site assessment, site feasibility studies, selection of remediation procedures, and engineered landfills. Design problems are based on real projects and involve visits from practicing engineers.]

CEE 451(4510) Microbiology for Environmental Engineering
Fall. 3 credits. Prerequisites: two semesters of college chemistry; organic chemistry or permission of instructor. R. E. Richardson.
Introduction to the fundamental aspects of microbiology and biochemistry that are pertinent to environmental engineering and science. Provides an overview of the characteristics of bacteria, Archaea, unicellular Eukaryotes (protozoa, algae, fungi), and viruses. Includes discussions of cell structure, bioenergetics and metabolism, and microbial genetics. Focus is then applied to topics pertinent to environmental engineering: pathogens; disease and immunity; environmental influences on microorganisms; roles of microbes in the carbon, nitrogen, and sulfur cycles; enzymes; molecular microbiology; and microbial ecology. This is an introductory course and is inappropriate for those who have taken BIOMI 290 or equivalent.

[CEE 452(4520) Water Supply Engineering
Fall. 3 credits. Prerequisite: CEE 351. Next offered 2008–2009. J. J. Bisogni.
Analysis of contemporary threats to human health from water supplies. Covers criteria and standards for potable-water quality; water-quality control theory; design of water supply facilities.]

CEE 453(4530) Laboratory Research in Environmental Engineering
Spring. 3 credits. Prerequisite: CEE 351 or permission of instructor. M. L. Weber-Shirk.
Laboratory investigations of reactor flow characteristics; acid rain/lake chemistry; contaminated soil-site assessment and remediation; and wastewater treatment. Design of laboratory experiments, data analysis, computerized process control, and model development are emphasized.

CEE 454(4540) Sustainable Small-Scale Water Supplies
Fall. 3 credits. M. L. Weber-Shirk.
This course covers the design and analysis of small-scale drinking water supply systems. We explore the technical, economic, and social constraints that form the sustainable space—i.e., the set of viable technologies that could be adopted progressively to improve the availability and quality of water. Students work in teams to design water supply and treatment systems.

CEE 455(4550) AguaClara: Sustainable Water Supply Project
Fall, spring. 3 credits. Prerequisite or corequisite: CEE 452 or CEE 454. Meets with CEE 255. M. L. Weber-Shirk.
Student teams conduct research, build working models, design full-scale prototypes, create design algorithms, and create educational materials for technology transfer to improve drinking water quality in Honduras. For more information see http://eswserver.cee.cornell.edu/aguaclara/.

CEE 461(4610) Urban Transportation Planning and Modeling
Spring. 3 credits. Prerequisite: CEE 361 or permission of instructor. A. H. Meyburg.
Covers modern transportation planning practice and the analytical tools that are necessary to engage in this field. Emphasizes passenger transportation in the urban context. The legislative, political, and economic contexts of urban transportation planning (UTP) are discussed. The course presents the travel demand estimation process and the associated models and approaches and provides insights in travel survey data acquisition.

CEE 463(4630) Transportation and Information Technology
Fall. 3 credits. J. R. Mbwana.
Improving the use of existing facilities has become an important objective in transportation planning. Examines the role of computer and telecommunications technologies to achieve these improvements. Focuses specific attention on the development of analyses to evaluate the benefits of inclusion of these technologies in transportation systems.

[CEE 464(4640) Transportation Systems Design]

CEE 465(4650) Environment/Energy and Transportation Planning and Management
Spring. 3 credits. Prerequisites: CEE 361 or permission of instructor. H. O. Gao.
For description, see CEE 665.

CEE 471(4710) Fundamentals of Structural Mechanics
Fall. 3 credits. Prerequisites: ENGRD 202, MATH 294. Staff.
Topics include beam bending; beams on elastic foundations; stability analysis for columns and beam-columns; linear elasticity; numerical solutions for linear elasticity problems; and applications including stress concentration, torsion, and plates.

CEE 472(4720) Introduction to the Finite Element Method
Fall. 3 credits. Prerequisites: CEE 371, 372, and 471. W. Aquino.
Covers the formulation of the finite element method in 2-D and 3-D continuum, basic 2-D and 3-D continuum isoparametric elements, modeling and programming aspects of the finite element method, and static and transient problems. A large part of the course is devoted to understanding element formulations, testing elements (patch test), and addressing problems such as shear and volumetric locking, among others. Emphasis is placed on understanding fundamental aspects of the method for making intelligent use of commercial software and obtaining a strong

background for moving to further study and research.

CEE 473(4730) Design of Concrete Structures

Spring. 4 credits. K. C. Hover.

Centered on the design of a multi-story building that is initially planned with masonry bearing walls and precast-prestressed concrete floors. The masonry walls are then replaced with steel beams and columns. In the next phase the precast concrete is replaced with cast-in-place reinforced concrete. Finally, the structural steel elements will be replaced with a reinforced concrete framing system. The course explore gravity loads, wind loads, and earthquake loads, and the behavior of individual members and the structure as a whole.

CEE 474(4740) Design of Steel Structures

Spring. 4 credits. Prerequisite: 341 or permission of instructor. C. Earls.

An introductory course focused on the use of solid and structural mechanics to qualify elementary steel building and bridge behavior to enable design.

CEE 475(4750) Concrete Materials and Construction

Spring. 3 credits. K. C. Hover.

Covers the materials science, structural engineering, and construction technology involved in the materials aspects of the use of concrete. Topics include cement chemistry and physics, mix design, admixtures, engineering properties, testing of fresh and hardened concrete, and the effects of construction techniques on material behavior.

[CEE 476(4760) Evaluation and Failure of Structures

Spring. 3 credits. Prerequisites: ENGRD 202, 261, and 203; CEE 371 and 473. Staff.

This course teaches material and structural evaluation through the lens of failure. The course builds upon and integrates what students have learned in courses in physics, mechanics, dynamics, materials science, structural modeling/analysis, and design. In addition, the course teaches the physics of methods used for condition assessment of structures (e.g., stress wave propagation, electromagnetic wave propagation, heat flow), introduces students to structural damage and assessment of damage caused by earthquake/wind loads on structures, and introduces students to blast/impact loadings on structures and the concept of progressive collapse.]

CEE 477(4770) Introduction to Composite Materials (also M&AE/T&AM 455[4550], MS&E 555[5550])

Fall. 3 credits. P. Petrina.

For description, see T&AM 455.

CEE 478(4780) Structural Dynamics and Earthquake Engineering

Spring. 3 credits. M. D. Grigoriu.

Covers modal analysis, numerical methods, and frequency-domain analysis. Introduction to earthquake-resistant design.

CEE 481(4781) LRFD-Based Engineering of Wood Structures (also BEE 481[4791])

Spring. 3 credits. Prerequisite: ENGRD 202.

For description, see BEE 481 under "College of Agriculture and Life Sciences."

CEE 492(4920) Engineers for a Sustainable World: Engineering in International Development

Fall. 3 credits. F. Vanek and P. Doing.

Engineering-based group service projects offer real-life engineering research and design experience, from problem formulation through implementation. They may be international or local, and may relate to any kind of engineering. Students work on interdisciplinary teams with a project supervisor and a partner community organization. Course readings and a writing assignment cover the relationship between engineering and international development, the philosophy and politics of technology, and ethics in engineering practice.

CEE 501–502 Design Project

Fall, spring. 3 credits each semester. Requirement for students in M.Eng. (civil and environmental) program. Staff.

CEE design projects present students with an exemplary design experience that reflects those carried out in the course of professional practice. Projects are typically performed by student design groups, and the topics reflect the diverse specialty areas of the civil and environmental engineering field as described below.

CEE 501–502(5021–5022) Project in Environmental and Water Resources Systems

CEE 501–502(5031–5032) Project in Environmental Fluid Mechanics and Hydrology

Staff.

CEE 501–502(5041–5042) Project in Geotechnical Engineering

T. D. O'Rourke.

Design of major geotechnical engineering project. Planning and preliminary design during fall semester; final design completed in January intersession.

CEE 501–502(5051–5052) Agua Clara: Sustainable Water Supply Project

M. Weber-Shirk.

CEE 501–502(5061–5062) Project in Transportation Engineering

Systems analysis of a substantial transportation service.

CEE 501–502(5071–5072) Project in Structural Engineering

C. Earls.

A project-centered course focusing on the design of a major engineering structure. Planning and a preliminary design are completed during the fall semester; the final design is completed in the January intersession.

CEE 501–502(5081–5082) Project in Civil Infrastructure Systems

Staff.

Analysis of a problem in civil infrastructure.

CEE 501–502(5073–5074) Project in Civil Engineering Materials

Staff.

CEE 504(5240) Applied Systems Engineering (also CS 504[5040], ECE/OR&IE 512[5120], M&AE 591[5910], SYSEN 510[5100])

Fall. 3 credits. Prerequisite: senior or graduate standing in engineering field; concurrent or recent (past two years) enrollment in group-based project with strong system design component approved by course instructor. A. R. George and R. Roundy.

For description, see SYSEN 510.

CEE 505(5252) System Architecture, Behavior, and Optimization (also CS 505[5050], ECE 513[5130], OR&IE 513[5142], M&AE 592[5920], SYSEN 520[5200])

Spring. 3 credits. Prerequisite: CEE/CS 504, ECE/OR&IE 512, M&AE 591, or SYSEN 520). Staff.

For description, see SYSEN 520.

CEE 509(5290) Heuristic Methods for Optimization (also CS/CIS 572[5720], OR&IE 533[5330])

Fall. 3 or 4 credits. Prerequisites: graduate standing or CS, ENGRD 211 or 321; ENGRD 320 or permission of instructor. C. A. Shoemaker.

Teaches heuristic search methods including simulated annealing, tabu search, genetic algorithms, derandomized evolution strategy, and random walk developed for optimization of combinatorial- and continuous-variable problems. Application project options include wireless networks, protein folding, job shop scheduling, partial differential equations, satisfiability, or independent projects. Statistical methods are presented for comparing algorithm results. Advantages and disadvantages of heuristic search methods for both serial and parallel computation are discussed in comparison with other optimization algorithms.

CEE 590(5800) Project Management

Fall, spring. 4 credits. Prerequisite: permission of instructor. F. J. Wayno.

Core graduate course in project management for people who will manage technical or engineering projects. Focuses both on the "technical" tools of project management (e.g., methods for planning, scheduling, and control) and the "human" side (e.g., forming a project team, managing performance, resolving conflicts), with somewhat greater emphasis on the latter.

CEE 591(5910) Engineering Management Project

Fall. 3 credits. Prerequisite: permission of instructor. Staff.

Intensive evaluation of the management aspects of a major engineering project or system. Most students work on a large group project in the area of project management, but students may also work singly or in small groups on an engineering management topic of special interest to them.

CEE 592(5920) Engineering Management Project

Spring. 3 credits. Prerequisite: permission of instructor. Staff.

Continuation of CEE 591.

CEE 593(5930) Engineering Management Methods

Fall. 3 credits. Prerequisites: CEE 323 and 304 or equivalent. M. A. Turnquist.

Methods for managing data and transforming data into information. Modeling as a means to synthesize information into knowledge that can form the basis for decisions and actions. Application of statistical methods and optimization to managerial problems in project design, scheduling, operations, forecasting, and resource allocation.

CEE 594(5940) Economic Methods for Engineering and Management (also ECON 494[4940])
Fall. 4 credits. Prerequisite: calculus, probability and statistics, and an economics course; senior or graduate standing or permission of instructor. R. E. Schuler.
Introduces economic concepts and uses them to select, calibrate and apply proper analytic decision tools in engineering design and management. Topics include market analysis and pricing strategies; production choices and cost estimation; input acquisition and employee motivation; project evaluation and the cost of capital; decision-making in risky and uncertain environments; industry structure, bidding strategies and game theory; plus the regulatory and ethical consequences of overall managerial strategies.

CEE 595(5950) Construction Planning and Operations
Fall. 3 credits. P. G. Carr.
The course prepares students for responsibilities in overseeing the engineering and management of construction; on time—on budget. Emphasis is placed on the management processes for organizing, planning, and controlling the activities of complex development and construction programs. Students study the contracts for engineering, architecture, and construction; focusing on cost estimation and schedule control, responsibilities and risks, and the relationships among owners, designers, contractors, and suppliers. The potential for project disruption is discussed with special emphasis on dispute resolution methods.

[CEE 596(5960) Management Issues in Forensic Engineering
Fall. 3 credits. Next offered 2008–2009. P. G. Carr.
Introduction to Management issues in Forensic Engineering, Contract Administration and Dispute Resolution, with particular emphasis on contract formation, performance, breach, and remedies. Through case studies in forensics, the engineer's standard of care and design obligations are explored. The engineer's technical and ethical duties to the client, the contractors, and the public are examined.]

CEE 597(5970) Risk Analysis and Management (also TOX 597[5970]
Spring. 3 credits. Prerequisite: introduction to probability and statistics (e.g., CEE 304, ENGRD 270, ILRST 210, BTRY 261, or AEM 210); two semesters of calculus; senior or graduate standing or permission of instructor. J. R. Stedinger.
Develops a working knowledge of risk terminology and reliability engineering, analytic tools and models used to analyze safety, environmental and technological risks, and social and psychological risk issues. Discussions address life risks in the United States historical accidents, natural hazards, threat assessment, transportation risks, industrial accidents, waste incineration, air pollution modeling, public health, regulatory policy, risk communication, and risk management.

CEE 601(6020) Seminar—Water Resources and Environmental Engineering
Fall. 1 credit. Staff.
Presents topics of current interest.

CEE 602(6070) Seminar—Civil Infrastructure
Fall, spring. 1 credit. Requirement for first-year graduate students. Staff.
Presents topics of current interest.

CEE 603(6080) Seminar—Engineering Systems and Management
Fall, spring. 1 credit. Staff.
Presents topics of current interest.

CEE 606(6860) Civil Infrastructure Systems
Fall. 3 credits. Prerequisites: probability and statistics course (CEE 304 or equivalent) and engineering economics course (CEE 323 or equivalent). Letter or S-U grades. F. Vanek.
Introduction to the framing and solution of civil infrastructure problems using a systems engineering approach. Systems tools, such as optimization, life-cycle cost analysis, decision analysis, simulation, Markov modeling, and risk analysis, are examined through case studies related to civil infrastructure.

CEE 609(6090) Numerical Methods for Engineers
Fall. 3 credits. P. J. Diamessis.
The primary focus is algorithm implementation within the context of engineering applications (spanning fluid and solid/fracture mechanics and beyond). Student projects will include parallel implementation using resources at the Theory Center. Course topics will include: Sources of error and error propagation, eigenvalue/eigenvector computation, solution of linear systems via direct or iterative methods and issues of parallel implementation, least squares approximation of lab/simulation data, solution of non-linear equations, interpolation in one and two dimensions, fast Fourier transforms (serial vs. parallel) and wavelets.

CEE 610(6100) Remote Sensing Fundamentals (also CSS 660[6100])
Fall. 3 credits. Prerequisite: facility with algebra, trigonometry, and univariate statistics. W. D. Philpot.
An introduction to equipment and methods used in obtaining information about earth resources and the environment from aircraft or satellite. Coverage includes sensors, sensor and ground-data acquisition, data analysis and interpretation, and project design.

CEE 615(6150) Digital Image Processing
Spring. 3 credits. Prerequisite: facility with algebra, trigonometry, and univariate statistics. W. D. Philpot.
An introduction to digital image-processing concepts and techniques, with emphasis on remote-sensing applications. Topics include image acquisition, enhancement procedures, spatial and spectral feature extraction, and classification, with an introduction to hyperspectral data analysis. Assignments require the use of image-processing software and graphics.

CEE 617(6015) Special Topics—Remote Sensing
On demand. 1–6 credits. W. D. Philpot.
Students may elect to undertake a project in remote sensing. The work is supervised by a professor in this subject area.

CEE 620(6200) Water-Resources Systems Engineering
Spring. 3 credits. Prerequisites: CEE 323 and 593 or BEE 475. D. P. Loucks.
Development and application of deterministic and stochastic optimization and simulation models for water-resources planning and management. Covers river-basin modeling, including water allocation to multiple purposes, reservoir design and operation, irrigation planning and operation, hydropower-capacity development, flow augmentation, flood control and protection, and water-quality prediction and control.

[CEE 621(6210) Stochastic Hydrology
Spring. 3 credits. Prerequisites: CEE 304 or permission of instructor. Offered on demand. J. R. Stedinger.
Course examines statistical, time series, and stochastic optimization methods used to address water resources planning and management problems involving uncertainty objectives and hydrologic inputs. Statistical issues include: maximum likelihood and moments estimators; censored data sets and historical information; probability plotting; Bayesian inference; regionalization methods; ARMA models; multivariate stochastic streamflow models; stochastic simulation; and stochastic reservoir-operation optimization models.]

[CEE 623(6230) Environmental Quality Systems Engineering
Fall. 3 credits. Prerequisites: MATH 294, optimization, and graduate standing or permission of instructor. C. A. Shoemaker.
Applications of optimization, simulation methods, and uncertainty analysis to the prevention and remediation of pollution. Case studies include: regional waste and wastewater treatment, restoration of dissolved oxygen levels in rivers, and reclamation of contaminated groundwater. Applications use linear programming, integer, dynamic, nonlinear programming, and sensitivity analysis.]

CEE 628(6021) Seminar—Environmental and Water Resources Systems Analysis
Spring. 1 credit. Prerequisite: permission of instructor. C. A. Shoemaker.
Graduate students and faculty members give informal lectures on various topics related to ongoing research in environmental or water resources systems planning and analysis.

[CEE 630(6300) Computational Fluid Dynamics for Environmental Flows
Spring. 3 credits. Next offered 2008–2009. P. J. Diamessis.
Higher-order spatial discretization schemes (spectral and compact-finite difference). One-dimensional nonlinear partial differential equations (Burgers eqn., Korteweg-DeVries eqn. and Shallow Water eqns.) and implications for environmental fluid flow simulations. Two-dimensional problems and fast iterative solvers. Numerical solution of the incompressible Navier-Stokes equations in an environmental/geophysical context. Advanced topics may include: Introduction to turbulence subgrid scale modeling in stratified/rotating flow, free surface flow modeling and representation of complex topography.]

CEE 631(6310) Computational Simulation of Flow and Transport in the Environment
Spring. 3 credits. Prerequisites: MATH 294 or equivalent, ENGRD 320 or experience in numerical methods and programming, and elementary fluid mechanics. P. L.-F. Liu.
Covers fundamental equations of saturated and unsaturated flow in porous media; flow in fractured media; numerical modeling of

transport in porous media; diffusion and advective diffusion in one, two, and three dimensions; anisotropy; and additional terms for reactive substances. Teaches various numerical methods including finite difference, finite elements, and boundary elements.

CEE 632(6320) Hydrology

Spring. 3 credits. Prerequisite: CEE 331. W. H. Brutsaert.

Introduction to hydrology as a description of the water cycle and the role of water in the natural environment, and other issues for environmental engineers and scientists. Covers: physical and statistical prediction methods for design related to hydrologic processes; hydrometeorology and evaporation; infiltration and base flow; surface runoff and channel routing; linear and nonlinear hydrologic systems; and storage routing and unit hydrograph methods.

[CEE 633(6330) Flow in Porous Media and Groundwater

Fall. 3 credits. Prerequisite: CEE 331. Next offered 2008–2009. Please contact professor if interested in this course. W. H. Brutsaert.

Fluid mechanics and equations of single-phase and multiphase flow; methods of solution. Applications involve aquifer hydraulics, pumping wells; drought flows; infiltration, groundwater recharge; land subsidence; seawater intrusion, miscible displacement; and transient seepage in unsaturated materials.]

[CEE 634(6340) Boundary Layer Meteorology

Fall. 3 credits. Prerequisite: CEE 331 or permission of instructor. Next offered 2008–2009. Please contact professor if interested in this course. W. H. Brutsaert.

Physical processes in the lower atmospheric environment: turbulent transport in the atmospheric boundary layer, surface-air interaction, disturbed boundary layers, radiation. Applications include sensible and latent heat transfer from lakes, plant canopy flow and evapotranspiration, turbulent diffusion from chimneys and cooling towers, and related design issues.]

[CEE 635(6350) Small and Finite Amplitude Water Waves

Spring. 3 credits. Taught based on demand; please contact professor if interested in this course. P. L.-F. Liu.

Reviews linear and nonlinear theories of ocean waves. Discusses the applicability of different wave theories to engineering problems.]

CEE 636(6360) Environmental Fluid Mechanics

Spring. 3 credits. Taught based on demand; please contact professor if interested in this course. E. A. Cowen.

Covers analytic and modeling perspectives of environmental flows; mechanics of layered and continuously stratified fluids: internal waves, density currents, baroclinic motions, and turbulence; jets and plumes and their behavior in the environment; turbulent diffusion, shear flow dispersion, and wave-induced mixing processes; and applications to mixing processes in rivers, lakes, estuaries, and the coastal ocean.

CEE 637(6370) Experimental Methods in Fluid Dynamics (also M&AE 627[6272])

Spring. 4 credits. Pre- or corequisites: CEE 331 or equivalent and CEE 304 or equivalent. E. A. Cowen.

Introduction to experimental data collection and analysis, in particular as they pertain to fluid flows. Covers computer-based experimental control, analog and digital data acquisition, discrete sampling theory, digital signal processing, uncertainty analysis. Also covers analog transducers, acoustic and laser Doppler velocimetry, full-field (2-D) quantitative imaging techniques. Includes laboratory experiments and a project.

CEE 638(6030) Seminar—Hydraulics

Spring. 1 credit. Requirement for graduate students majoring in hydraulics or hydraulic engineering. Open to undergraduates and graduates. Staff.

Topics of current interest in fluid mechanics, hydraulic engineering, and hydrology.

CEE 639(6035) Special Topics in Hydraulics

On demand. 1–6 credits. Staff.

Special topics in fluid mechanics, hydraulic engineering, or hydrology.

CEE 640(6400) Foundation Engineering

Fall. 3 credits. Prerequisite: CEE 341. T. D. O'Rourke.

Covers soil exploration, sampling, and in-situ testing techniques; bearing capacity, stress distribution, and settlement; design of shallow and deep foundations; compaction and site preparation; and seepage and dewatering of foundation excavations.

CEE 641(6410) Retaining Structures and Slopes

Spring. 3 credits. Prerequisite: CEE 341. T. D. O'Rourke.

Covers Earth pressure theories; design of rigid, flexible, braced, tied-back, slurry wall, soil nailing, and reinforced soil structures; stability of excavation, cut, and natural slopes; and design problems stressing application of course material under field conditions of engineering practice.

[CEE 644(6440) Environmental Site and Remediation Engineering

Spring. 3 credits. Prerequisite: CEE 341 or equivalent or permission of instructor. Next offered 2008–2009. T. D. O'Rourke.

Covers principles of hydrogeology, contaminant migration, and remediation technologies related to geotechnical and environmental engineering. Emphasizes environmental site assessment, site feasibility studies, selection of remediation procedures, and engineered landfills. Design problems are based on real projects and involve visits from practicing engineers.]

CEE 649(6045) Special Topics in Geotechnical Engineering

On demand. 1–6 credits. Staff.

Supervised study of special topics not covered in the formal courses.

CEE 653(6530) Water Chemistry for Environmental Engineering

Fall. 3 credits. Prerequisite: one semester of college chemistry or permission of instructor. L. W. Lion.

Covers principles of chemistry applicable to the understanding, design, and control of water and wastewater treatment processes and to reactions in receiving waters. Topics include chemical thermodynamics, reaction kinetics, acid-base equilibria, mineral precipitation/dissolution, and electrochemistry. Focuses on the mathematical description of chemical reactions relevant to engineered processes and natural systems, and the numerical or graphical solution of these problems.

[CEE 654(6540) Aquatic Chemistry

Spring. 3 credits. Prerequisite: CEE 653 or CHEM 287–288. J. J. Bisogni.

Applies concepts of chemical equilibria to natural aquatic systems. Topics include acid-base reactions, buffer systems, mineral precipitation, coordination and redox reactions, Eh-pH diagrams adsorption phenomena, humic acid chemistry, and chemical-equilibria computational techniques. In-depth coverage of topics covered in CEE 653.]

CEE 655(6550) Transport, Mixing, and Transformation in the Environment

Fall. 3 credits. Prerequisite: CEE 331. P. L. Liu.

Application of fluid mechanics to problems of transport, mixing, and transformation in the water environment. Introduction to advective, diffuse, and dispersive processes in the environment. Boundary interactions: air-water and sediment-water processes. Introduction to chemical and biochemical transformation processes. Applications to transport, mixing, and transformation in rivers, lakes, and coastal waters.

CEE 656(6560) Physical/Chemical Process

Fall. 3 credits. Pre- or corequisite: CEE 653 or permission of instructor. J. J. Bisogni.

Theoretical and engineering aspects of chemical and physical phenomena and processes applicable to the removal of impurities from water, wastewater, and industrial wastes and to their transformation in the environment. Analysis and design of treatment processes and systems.

CEE 657(6570) Biological Processes

Spring. 3 credits. Prerequisites: introductory microbiology and CEE 656, or permission of instructor. J. M. Gossett.

Theoretical and engineering aspects of biological phenomena and processes applicable to the removal of impurities from water, wastewater, and industrial wastes and to their transformation in the environment. Bioenergetics analysis, stoichiometry, biokinetic, and design of biological treatment process.

CEE 658(6580) Biodegradation and Biocatalysis

Spring. 3 credits. Prerequisites: CEE 451 or BIOMI 290 or equivalent; CEE 351 or CHEME 390 or permission of instructor. R. E. Richardson.

Students explore the use of microbes in biodegradation and biocatalysis as well as the molecular techniques (i.e., analysis of DNA, RNA, and proteins) commonly used in these applications. Lectures cover enzyme classes and kinetics, selective isolation of organisms with desired bioconversion capabilities, effects of environmental parameters and cell-to-cell communication on gene expression, methods in microbial molecular biology, and contemporary case studies in biodegradation and biocatalysis. Laboratory sessions give students hands-on experience in molecular and analytical methods. Student teams design and then construct a bioreactor employing their own environmental isolates that degrade a selected contaminant or produce a desired compound.

CEE 659(6051) Seminar—Environmental Quality Engineering

Spring. 1 credit. Prerequisite: graduate students in environmental engineering. R. E. Richardson.

Presentation and discussion of current research in environmental engineering.

CEE 661(6610) Urban Transportation Planning and Modeling

Spring. 3 credits. Prerequisite: CEE 361 or permission of instructor. A. H. Meyburg.

For description, see CEE 461.

CEE 662(6620) Urban Transportation Network Design and Analysis

Fall. 3 credits. Prerequisite: CEE 361 or permission of instructor. M. A. Turnquist.

Covers the development and use of mathematical models for the design and analysis of urban transportation networks, including formulations and solution procedures based on user equilibrium and stochastic user equilibrium. Students apply these tools to a substantive real-world case study.

[CEE 663(6630) Network Flows and Algorithms]

CEE 665(6650) Environment/Energy and Transportation Planning and Management

Spring. 3 credits. Prerequisites: CEE 361 or permission of instructor. H. O. Gao.

The course focuses on the nexus of transportation and environment, energy, and climate-change concerns. It is interdisciplinary: drawing upon transportation, environment, urban planning, statistics, economics, and policy. The course covers both the theoretical and practical aspects of relevant topics including mobile emissions inventory estimation, renewable fuels, air quality impact and life cycle benefit assessment of alternative fuels/vehicles, Intelligent Transportation Systems (ITS) and urban sprawl, and congestion mitigation and air quality (CMAQ). Students will apply course materials to real-world cases and projects.

CEE 668(6060) Seminar—Transportation System Engineering

Fall, spring. 1 credit. Staff.

Presents topics of current interest.

CEE 671(6710) Fundamentals of Structural Mechanics

Fall. 3 credits. Prerequisites: ENGRD 202, MATH 294. Staff.

Topics include beam bending, beams on elastic foundation, stability analysis for columns and beam-columns, linear elasticity, numerical solutions for linear elasticity problems, and applications including stress concentration, torsion, and plates.

CEE 672(6720) Introduction to the Finite Element Method

Fall. 3 credits. Prerequisites: CEE 371, 372, and 471. W. Aquino.

Covers the formulation of the finite element method in 2-D and 3-D continuum, basic 2-D and 3-D continuum isoparametric elements, modeling and programming aspects of the finite element method, and static and transient problems. A large part of the course is devoted to understanding element formulations, testing elements (patch test), and addressing problems such as shear and volumetric locking, among others. Emphasis is placed on understanding fundamental aspects of the method for making intelligent use of commercial software and obtaining a strong background for moving to further study and research.

CEE 673(6730) Design of Concrete Structures

Spring. 4 credits. Prerequisite: CEE 371 or permission of instructor. K. C. Hover.

Centered on the design of a multi-story building that is initially planned with masonry bearing walls and precast-prestressed concrete floors. The masonry walls are then replaced with cast-in-place reinforced concrete. Finally, the structural steel elements are replaced with a reinforced concrete framing system. The course explores gravity loads, wind loads, and earthquake loads, and the behavior of individual members and the structure as a whole.

CEE 675(6750) Concrete Materials and Construction

Spring. 3 credits. K. C. Hover.

Covers the materials science, structural engineering, and construction technology involved in the materials aspects of the use of concrete. Topics include cement chemistry and physics, mix design, admixtures, engineering properties, testing of fresh and hardened concrete, and the effects of construction techniques on material behavior.

CEE 676(6760) Advanced Composite Materials (also T&AM 655[6550], M&AE/MS&E 655[6550])

Spring. 4 credits. CEE 477/T&AM 455/555 not a prerequisite but excellent background.

For description, see T&AM 655.

[CEE 677(6770) Engineering Analysis

Fall. 3 credits. Prerequisite: permission of instructor. Next offered 2008–2009. M. D. Grigoriu.

Vector spaces, linear transformations, and eigenvalue problems with applications to matrix structural analysis, linear dynamics, stability, and principal stresses, strains, and moments of inertia. Fourier analysis for periodic and non-periodic functions, with applications to the solution of ordinary differential equations, beams, plates, and other structural mechanics problems. Partial differential equations with applications to the analysis of static and dynamic response of continuous systems and transport problems.]

CEE 678(6780) Structural Dynamics and Earthquake Engineering

Spring. 3 credits. M. D. Grigoriu.

Covers modal analysis, numerical methods, and frequency-domain analysis. Introduces earthquake-resistant design.

CEE 679(6760) Evaluation and Failure of Structures

Spring. 3 credits. Staff.

Teaches material and structural evaluation through the lens of failure. Builds upon and integrates what students have learned in courses in physics, mechanics, dynamics, materials science, structural modeling/analysis, and design. In addition, the course teaches the physics of methods used for condition assessment of structures (e.g., stress wave propagation, electromagnetic wave propagation, heat flow), introduces students to structural damage and assessment of damage caused by earthquake/wind loads on structures, and introduces students to blast/impact loadings on structures.

CEE 690(6900) Creativity, Innovation, and Leadership

Spring. 3 credits. Pre- or corequisite: CEE 590 or permission of instructor. F. J. Wayno.

Graduate course designed to help aspiring engineering managers to better understand individual creativity and organizational innovation and to develop the required skills to play a productive role in fostering both. Not incidentally, the course will also help students who take it to become more creative themselves. The course is highly participative and has a flow that moves from the individual-—to the group—-to the organization, with theory, research results, and practical skills-development woven seamlessly together.

CEE 692(6095) Special Topics in Engineering Management

On demand. 1–6 credits. Staff.

Individually supervised study of one or more specialized topics not covered in regular courses.

CEE 693(6930) Public Systems Modeling

Fall. 4 credits. D. P. Loucks.

An introduction to the art of model building and use, especially related to public sector planning and management issues. The course will focus on the quantitative systems approach for identifying and evaluating alternative possible decisions and their physical, economic, environmental, and social impacts. Modeling methods include various deterministic and probabilistic optimization and simulation models, decision analysis, evolutionary search algorithms, and statistical models applied to a variety of public sector issues. The aim of all of this "modeling technology" is to help us generate and communicate information that can assist and better inform public decision making.

CEE 694(6940) Research in Engineering Management

On demand. 1–6 credits. Staff.

The student may select an area of investigation in engineering management. Results should be submitted to the instructor in charge in the form of a research report.

CEE 697(6075) Special Topics in Structural Engineering

On demand. 1–6 credits. Staff.

Individually supervised study or independent design or research in specialized topics not covered in regular courses. Occasional offering of such special courses as Shell Theory and Design, and Advanced Topics in Finite Element Analysis.

CEE 710(7010) Research—Remote Sensing

On demand. 1–6 credits. W. D. Philpot.

For students who want to study one particular area in depth. The work may take the form of laboratory investigation, field study, theoretical analysis, or development of design procedures.

CEE 722(7020) Environmental and Water Resources Systems Analysis Research

On demand. 1–6 credits. Prerequisite: permission of instructor. Preparation must be suitable to investigation to be undertaken. Staff.

Investigations of particular environmental or water resources systems problems.

CEE 729(6025) Special Topics in Environmental and Water Resources Systems Analysis
Offered on demand. 1–6 credits. D. P. Loucks.
Supervised study, by individuals or small groups, of one or more specialized topics not covered in regular courses.

CEE 735(7030) Research in Environmental Fluid Mechanics and Hydrology
On demand. 1–6 credits. Staff.
The student may select an area of investigation in fluid mechanics, hydraulic engineering, or hydrology. The work may be either experimental or theoretical in nature. Results should be submitted to the instructor in charge in the form of a research report.

CEE 736(7360) Turbulence and Turbulent Mixing in Environmental Stratified Flows
Spring. 3 credits. Prerequisite: CEE 655 or a second course in fluid mechanics or with instructor's permission. P. J. Diamessis.
Fundamentals of stably stratified flows, stratified homogeneous turbulence (spectra, lengthscales, and timescales), kinematics of diapycnal mixing, basic turbulent flow processes in homogeneous and stratified fluids (shear layers, wakes, boundary layers, etc.), energy budget analysis, and parameterizations of geophysical turbulence. Additional topics may include: fossil turbulence theory and vortex-internal wave decomposition in strongly stratified turbulence.

CEE 740(7400) Engineering Behavior of Soils
Fall. 3 credits. Prerequisite: CEE 341. H. E. Stewart.
Detailed study of the physiochemical nature of soil. Stress states due to geostatic loading and stress-history effects. In-depth evaluation of stress-strain-strength, compressibility, and hydraulic conductivity of natural soils.

CEE 741(7410) Rock Engineering
Fall. 3 credits. Prerequisite: CEE 341 or permission of instructor. Recommended: introductory geology. T. D. O'Rourke.
Geological and engineering classifications of intact rock, discontinuities, and rock masses. Includes laboratory and field evaluation of properties. Covers: stress states and stress analysis; design of foundations on, and openings in, rock masses; analysis of the stability of rock slopes; and rock blasting.

[CEE 744(7440) Advanced Foundation Engineering
Spring. 2 credits. Prerequisite: CEE 640. Next offered 2008–2009. F. H. Kulhawy.
Continuation of CEE 640, with detailed emphasis on special topics in soil-structure interaction. Typical topics include lateral and pullout loading of deep foundations, pile group behavior, foundations for offshore structures, foundations for special structures.]

CEE 745(7450) Soil Dynamics
Spring. 3 credits. Prerequisite: permission of instructor. H. E. Stewart.
Study of soil behavior under dynamic loading conditions. Foundation design for vibratory loadings. Introductory earthquake engineering including field and laboratory techniques for determining dynamic soil properties and liquefaction potential. Covers design of embankments and retaining structures under dynamic loading conditions.

[CEE 746(7460) Embankment Dam Engineering
Spring. 2 credits. Prerequisites: CEE 641 and 741, or permission of instructor. Next offered 2009–2010. F. H. Kulhawy.
Principles of analysis and design for earth and rockfill dams. Materials, construction methods, internal and external stability, seepage and drainage, performance monitoring, abutment and foundation evaluation. Introduction to tailings dams.]

CEE 749(7040) Research in Geotechnical Engineering
On demand. 1–6 credits. Staff.
For students who want to pursue a particular geotechnical topic in considerable depth.

CEE 750(7050) Research in Environmental Engineering
On demand. 1–6 credits. Staff.
For students who want to study a particular area in depth. The work may take the form of laboratory investigation, field study, theoretical analysis, or development of design and analysis procedures.

CEE 759(6055) Special Topics in Environmental Engineering
On demand. 1–6 credits. Staff.
Supervised study in special topics not covered in formal courses.

CEE 762(7620) Practicum in Modeling Transportation Systems
Fall. 3 credits. Prerequisites: CEE 661, 662, and 663. L. K. Nozick.

CEE 764(6065) Special Topics in Transportation
On demand. 1–6 credits. Staff.
Advanced subject matter not covered in depth in other regular courses.

[CEE 770(7700) Engineering Fracture Mechanics
Fall. 3 credits. Prerequisite: CEE 672 or equivalent and T&AM 753, or permission of instructor. Next offered 2008–2009. A. Ingraffea.
Computational and physical modeling of crack growth processes. Finite and boundary element-based simulation of brittle fracture initiation and propagation, fatigue crack growth, and elasto-plastic and cohesive approaches to inelastic crack growth. Element formulation, meshing and remeshing, interactive steering. Case studies across scales from geomechanics to micromechanics, and including metals, ceramics, and polymers. Laboratory techniques for fracture toughness, crack growth rate, and trajectory testing.]

[CEE 771(7710) Stochastic Mechanics in Science and Engineering
Fall. 3 credits. Prerequisite: permission of instructor. Next offered 2008–2009. M. D. Grigoriu.
Review of probability theory, stochastic processes, and Ito formula with illustrations by Monte Carlo Simulation. Analytical and numerical methods for solving stochastic problems defined by algebraic, differential, and integral equations with random/deterministic coefficients and random/deterministic input. Applications include: solution of Laplace, transport, Schrodinger, and other deterministic partial differential equations; dynamic systems subjected to Gaussian and non-Gaussian noise; random eigenvalue problems; and homogenization, structure evolution, and pattern formation for random heterogeneous materials.]

[CEE 772(7720) Random Vibration
Fall. 3 credits. Prerequisites: M&AE 326 and OR&IE 260, or equivalent, and permission of instructor. Next offered 2008–2009. M. D. Grigoriu.
Reviews random-process theory, simulation, and first-passage time. Linear random vibration: second-moment response descriptors and applications from fatigue; seismic analysis; and response to wind, wave, and other non-Gaussian load processes. Nonlinear random vibration: equivalent linearization, perturbation techniques, Fokker-Planck and Kolomogorov equations, Itô calculus, and applications from chaotic vibration, fatigue, seismic analysis, and parametrically excited systems.]

[CEE 773(7730) Structural Reliability
Fall. 3 credits. Prerequisite: permission of instructor. Next offered 2008–2009. M. D. Grigoriu.
Review of probability theory, practical measures for structural reliability, second-moment reliability indices, probability models for strength and loads, probability-based design codes, reliability of structural systems, imperfection-sensitive structures, fatigue, stochastic finite-element techniques, and elementary concepts of probabilistic fracture mechanics.]

CEE 774(7740) Advanced Structural Concrete
Fall. 3 credits. Staff.
Covers the fundamental aspects of the mechanical behavior of concrete subjected to axial and multiaxial states of stress, rate effects, time-dependent deformations, and multiscale modeling. Includes the behavior of reinforced concrete membrane elements subjected to plane states of stress, torsion, limit analysis, and gives an introduction to finite element modeling of reinforced concrete structures.

CEE 775(7750) Nonlinear Finite Element Analysis
Spring. 3 credits. W. Aquino.
Covers fundamental aspects of nonlinear finite element analysis including geometric and material nonlinearity. Also covers total and updated lagrangian formulations, implementation of constitutive models, numerical solutions of global nonlinear systems of equations, and regularization techniques for softening materials.

[CEE 776(7760) Advanced Topics in Stability
Spring. 3 credits. Prerequisite: CEE 374 or equivalent. Next offered 2008–2009. C. Earls.]

CEE 777(7770) Computational Solid and Structural Mechanics
Spring. 3 credits. Staff.
This course covers the formulation and numerical solution of problems of solids and structures using the finite element method. Topics include a review of solid mechanics: nonlinear kinematics, invariance, first and second law of thermodynamics, and constitutive equations with internal variables; strong forms and weak forms; implicit and explicit algorithms; variants of Newton's method; and Lagrangian and Eulerian formulations. Application topics are chosen from the following areas: 3D finite elasticity, fully nonlinear beams and shells, distributed and discrete damage, contact-impact, and plasticity.

CEE 779(7790) Advanced Behavior of Metal Structures
Fall. 4 credits. Prerequisite: CEE 341 or permission of instructor. C. Earls.
An advanced course focused on the use of solid and structural mechanics to quantify more complex aspects of metal building behavior so as to enable more sophisticated approach to design.

CEE 783(7073) Civil and Environmental Engineering Materials Project
On demand. 1–3 credits. Staff.
Individual projects or reading and study assignments involving engineering materials.

CEE 785(7070) Research in Structural Engineering
On demand. 1–6 credits. Staff.
Pursues a branch of structural engineering beyond what is covered in regular courses. Theoretical or experimental investigation of suitable problems.

CEE 786(7860) Special Topics in Structural Engineering
On demand. 1–6 credits. Staff.
Individually supervised study or independent design or research in specialized topics not covered in regular courses.

CEE 810(8100) Thesis—Remote Sensing
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. W. D. Philpot.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 820(8200) Thesis—Environmental and Water Resource Systems
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 830(8300) Thesis—Environmental Fluid Mechanics and Hydrology
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 840(8400) Thesis—Geotechnical Engineering
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 850(8500) Thesis—Environmental Engineering
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 860(8600) Thesis—Transportation Systems Engineering
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 880(8700) Thesis—Structural Engineering
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

CEE 890(8800) Thesis—Civil Infrastructure Systems
Fall, spring. 1–12 credits. Students must register for credit with professor at start of each semester. Staff.
The student selects a thesis research topic with the advice of the faculty member in charge and pursues it either independently or in conjunction with others working on the same topic.

COMPUTER SCIENCE

E. Tardos, chair; W. Arms, G. Bailey, K. Bala, K. Birman, C. Cardie, R. Caruana, R. L. Constable, D. Fan, P. Francis, J. Gehrke, D. Greenberg, D. Gries, J. Halpern, J. E. Hopcroft, D. Huttenlocher, D. James, T. Joachims, U. Keich, J. Kleinberg, R. Kleinberg, D. Kozen, L. Lee, S. Marschner, A. Myers, R. Pass, R. Rugina, F. B. Schneider, D. Schwartz, B. Selman, D. Shmoys, E. G. Sirer, R. Teitelbaum, C. Van Loan, R. Zabih

The Department of Computer Science is part of the College of Arts and Sciences, Computing and Information Science (CIS), and the College of Engineering. For complete course descriptions, see the Computer Science listing in the CIS section.

CS 099(1109) Fundamental Programming Concepts
Summer. 2 credits. Prerequisite: freshman standing. Credit may not be applied toward engineering degree. S-U grades only.

[CS 100H(1113) Computing Using Java—Honors
Fall or spring. 4. credits.]

CS 100J(1110) Introduction to Computing Using Java
Fall, spring, summer. 4 credits. Assumes basic high school mathematics (no calculus), but no programming experience.

CS 100M(1112) Introduction to Computing Using MATLAB
Fall, spring. 4 credits. Corequisite: MATH 111, 191, or equivalent. Assumes student is comfortable with mathematics (at level of one semester of calculus) but has no prior programming experience.

CS 100R(1114) Introduction to Computing Using MATLAB and Robotics
Fall and/or spring. 4 credits. Prerequisite: some programming experience.

CS 101J(1130) Transition to Object-Oriented Programming
Fall, spring, summer. 1 credit. Prerequisite: one course in programming.

CS 101M(1132) Transition to MATLAB
Fall, spring, summer. 1 credit. Prerequisite: one course in programming.

CS 113(2000) Introduction to C
Fall, spring, usually weeks 1–4. 1 credit. Prerequisite: CS 100 (1110 or 1112) or equivalent programming experience. Credit granted for both CS 113 and 213 only if 113 taken first. S-U grades only.

CS 114(2006) Unix Tools
Fall, usually weeks 5–8. 1 credit. Prerequisite: CS 100 (1110 or 1112) or equivalent programming experience. Recommended: knowledge of at least one programming language. S-U grades only.

CS 130(1300) Introductory Design and Programming for the Web (also INFO 130[1300])
Fall. 3 credits. Prerequisite: none. No computer background necessary.

CS 165(1610) Computing in the Arts (also ART 175, CIS 165[1610], ENGRI 165[1610], MUSIC 165[1465], PSYCH 165[1650])
Fall. 3 credits. Recommended: good comfort level with computers and some of the arts.

CS 167(1620) Visual Imaging in the Electronic Age (also ARCH 459[4509], ART 170[1700], CIS 167[1620], ENGRI 167[1670])
Fall. 3 credits.
For description, see ART 170.

CS 170(1710) Introduction to Cognitive Science (also COGST 101[1010], LING 170[1700], PHIL 191[1910], PSYCH 102[1020]) (formerly CS 101)
Fall, summer. 3 credits.
For description, see COGST 101.

[CS 172(1700) Computation, Information, and Intelligence (also COGST 172, ENGRI 172[1700], INFO 172[1700])
Fall or spring. 3 credits. Prerequisite: some knowledge of differentiation; freshman standing or permission of instructor. Next offered 2008–2009.]

CS 211(2110) Object-Oriented Programming and Data Structures (also ENGRD 211[2110])
Fall, spring, summer. 3 credits. Prerequisite: CS 100J, CS 101J, or CS 100H or CS 100M if completed before fall 2007 or equivalent course in Java or C++.

CS 212(2111) Programming Practicum
Fall, spring. 1 credit. Pre- or corequisite: CS/ENGRD 211. Letter grades only.

CS 213(2134) C++ Programming
Fall. 2 credits. Prerequisite: CS 100 or equivalent programming experience. Students who plan to take CS 113 and 213 must take 113 first. S-U grades only.

CS 214(2136) Advanced UNIX Programming and Tools
Spring, usually weeks 5–8. 1 credit. Prerequisite: CS 114 or equivalent. S-U grades only.

CS 215(2004) Introduction to C#
Spring, usually weeks 5–8. 1 credit. Prerequisite: CS/ENGRD 211 or equivalent experience. S-U grades only.

CS 230(2300) Intermediate Design and Programming for the Web (also INFO 230[2300])
Spring. 3 credits. Prerequisite: CS 130 or equivalent knowledge.

CS 280(2800) Discrete Structures
Fall, spring. 3 credits. Pre- or corequisite: CS 100 or permission of instructor.

CS 285(2850) Networks (also ECON 204[2040], INFO 204[2040], SOC 209[2090])
Spring. 4 credits. Prerequisite: none.

CS 312(3110) Data Structures and Functional Programming
Fall, spring. 4 credits. Prerequisite: CS 211 and 212 or equivalent programming experience. Should not be taken concurrently with CS 314 or 316.

CS 314(3420) Computer Organization (also ECE 314[3140])
Spring. 4 credits. Prerequisite: CS 211 or ENGRD 230. Should not be taken concurrently with CS 312.

CS 316(3410) Systems Programming
Fall. 4 credits. Prerequisites: CS 211 or equivalent programming experience. Should not be taken concurrently with CS 312.

[CS 321(3510) Numerical Methods in Computational Molecular Biology (also BIOBM 321[3210], ENGRD 321[3510])
Fall. 3 credits. Prerequisites: at least one course in calculus (e.g., MATH 106, 111, or 191) and a course in linear algebra (e.g., MATH 221 or 294 or BTRY 417); CS 100 or equivalent and some familiarity with iteration, arrays, and procedures; knowledge of discrete probability and random variables at the level of CS 280.]

CS 322(3220) Introduction to Scientific Computation (also ENGRD 322[3220])
Spring, summer. 3 credits. Prerequisites: CS 100 and MATH 221 or 294; knowledge of discrete probability and random variables at the level of CS 280.

CS 324(3740) Computational Linguistics (also COGST 424[4240], LING 424[4424])
Fall, spring. 4 credits. Prerequisites: LING 203. Recommended: CS 114. Labs involve work in Unix environment.
For description, see LING 424.

CS 330(3300) Data-Driven Web Applications (also INFO 330[3300])
Fall. 3 credits. Prerequisite: CS/ENGRD 211. CS majors may use only one of the following toward their degree: CS/INFO 330 or CS 433.

CS 372(3700) Explorations in Artificial Intelligence (also INFO 372[3720])
Spring. 3 credits. Prerequisites: MATH 111 or equivalent, a statistics course, and CS/ENGRD 211 or permission of instructor.

CS 381(3810) Introduction to Theory of Computing
Fall, summer. 3 credits. Prerequisite: CS 280 or permission of instructor.

[CS 400(4150) The Science of Programming
Fall. 3 credits. Prerequisite: CS 211.]

[CS 411(4110) Programming Languages and Logics
Fall or spring. 4 credits. Prerequisite: CS 312 or permission of instructor. Next offered 2008–2009.]

CS 412(4120) Introduction to Compilers
Spring. 3 credits. Prerequisites: CS 312 or permission of instructor and CS 314 or 316. Corequisite: CS 413.

CS 413(4121) Practicum in Compilers
Spring. 2 credits. Corequisite: CS 412.

CS 414(4410) Operating Systems
Fall, spring, summer. 3 credits. Prerequisite: CS 314 or 316. Corequisite: CS 415 in spring only.

CS 415(4411) Practicum in Operating Systems
Fall, spring. 2 credits. Corequisite: CS 414.

CS 416(4420) Computer Architecture (also ECE 475[4750])
Fall. 4 credits. Prerequisites: ENGRD 230 and CS/ECE 314.
For description, see ECE 475.

CS 419(4450) Computer Networks
Spring. 4 credits. Pre- or corequisite: CS 414 or permission of instructor.

CS 421(4210) Numerical Analysis and Differential Equations (also MATH 425[4250])
Fall. 4 credits. Prerequisites: MATH 221 or 294 or equivalent, one additional mathematics course numbered 300 or above, and knowledge of programming.

CS 422(4220) Numerical Analysis: Linear and Nonlinear Problems (also MATH 426[4260])
Spring. 4 credits. Prerequisites: MATH 221 or 294 or equivalent, one additional mathematics course numbered 300 or above, and knowledge of programming.

CS 426(4520) Introduction to Bioinformatics
Spring. 4 credits. Prerequisites: CS/ENGRD 211, CS 280.

[CS 428(4510) Introduction to Computational Biophysics
Fall. 3 credits. Prerequisite: CS 100, CHEM 211 or equivalent, MATH 221, 293 or 294, PHYS 112 or 213, or permission of instructor. Recommended: BIOBM 330.]

CS 430(4300) Information Retrieval (also INFO 430[4300])
Fall. 3 credits. Prerequisite: CS 211 or equivalent.

CS 431(4302) Web Information Systems (also INFO 431[4302])
Spring. 3 credits. Prerequisites: CS 211 and some familiarity with web site technology.

CS 432(4320) Introduction to Database Systems
Fall. 3 credits. Prerequisites: CS 312 (or CS 211, 212 and permission of instructor).

CS 433(4321) Practicum in Database Systems
Fall. 2 credits. Pre- or corequisite: CS 432. CS majors may use only one of the following toward their degree: CS/INFO 330 or CS 433.

CS 465(4620) Introduction to Computer Graphics (also ARCH 374[3740])
Fall. 3 credits. Prerequisite: CS/ENGRD 211.

CS 466(4621) Computer Graphics Practicum
Fall. 2 credits. Pre- or corequisite: CS 465.

CS 472(4700) Foundations of Artificial Intelligence
Fall. 3 credits. Prerequisites: CS/ENGRD 211 and CS 280 or equivalent.

CS 473(4701) Practicum in Artificial Intelligence: Robotics and Embodied AI (also M&AE 473[4730])
Fall. 2 credits. Pre- or corequisite: CS 472.

[CS 474(4740) Introduction to Natural Language Processing (also COGST 474[4740], LING 474[4474])
Fall or spring. 4 credits. Prerequisite: CS 216. Next offered 2008–2009.]

[CS 475(4702) Artificial Intelligence: Uncertainty and Multi-Agent Systems
Spring. 4 credits. Prerequisites: CS/ENGRD 211 and CS 280 or equivalent. Next offered 2008–2009.]

CS 478(4780) Machine Learning
Spring. 4 credits. Prerequisites: CS 280, 312, and basic knowledge of linear algebra and probability theory.

CS 482(4820) Introduction to Analysis of Algorithms
Spring, summer. 4 credits. Prerequisites: CS 280 and 312.

[CS 483(4812) Quantum Computation (also PHYS 481/681[4481/7681])
Spring. 2 credits. Prerequisite: familiarity with theory of vector spaces over complex numbers. Next offered 2008–2009.
For description, see PHYS 481.]

[CS 485(4850) Mathematical Foundations for the Information Age
Spring. 4 credits. Prerequisite: CS 381.]

CS 486(4860) Applied Logic (also MATH 486[4860])
Spring. 4 credits. Prerequisites: MATH 222 or 294, CS 280 or equivalent (e.g., MATH 332, 432, 434, 481), and some additional course in mathematics or theoretical computer science.

CS 487(4830) Introduction to Cryptography
Fall. 4 credits. Prerequisites: CS 280 (or equivalent), CS 381 (or mathematical maturity), or permission of instructor.

CS 490(4999) Independent Reading and Research
Fall, spring. 1–4 credits.

CS 501(5150) Software Engineering
Spring. 4 credits. Prerequisite: CS 211 or equivalent experience programming in Java or C++.

CS 513(5430) System Security
Fall. 4 credits. Prerequisites: CS 414 or 419 and familiarity with Java, C, or C# programming languages.

CS 514(5410) Intermediate Computer Systems
Spring. 4 credits. Prerequisite: CS 414 or permission of instructor.

CS 516(5420) Parallel Computer Architecture (also ECE 572[5720])
Fall. 4 credits. Prerequisite: ECE 475.
For description, see ECE 572.

For description, see ECE 572.

[CS 519(5450) Advanced Computer Networks (also CS 619[6450])
Fall or spring. 4 credits. Prerequisites: CS 419 or permission of instructor. Next offered 2008–2009.]

CS 530(5300) The Architecture of Large-Scale Information Systems (also INFO 530[5300])
Spring. 4 credits. Prerequisite: CS/INFO 330 or 432.

CS 565(5640) Computer Animation (also ART 273[2703], CIS 565[5640])
Fall. 4 credits. Prerequisite: none.
For description, see ART 273.

CS 566(5642) Advanced Animation (also ART 372, CIS 566[5642])
Spring. 4 credits. Prerequisite: none.
For description, see ART 372.

[CS 567(5643) Physically Based Animation for Computer Graphics
Spring. 4 credits. Prerequisites: CS/ENGRD 322 and/or CS 465 or permission of instructor. Offered alternate years; next offered 2008–2009.]

CS 569(5620) Interactive Computer Graphics
Spring. 4 credits. Prerequisite: CS 465.

CS 572(5722) Heuristic Methods for Optimization (also CEE 509[5090], OR&IE 533[5340])
Fall. 3 or 4 credits. Prerequisites: CS/ENGRD 211 or 322 or CEE/ENGRD 320, or graduate standing, or permission of instructor.
For description, see CEE 509.

CS 578(5780) Empirical Methods in Machine Learning and Data Mining
Fall. 4 credits. Prerequisites: CS 280 and 312 or equivalent.

CS 611(6110) Advanced Programming Languages
Fall. 4 credits. Prerequisite: graduate standing or permission of instructor.

CS 612(6120) Advanced Compilers and Program Analyzers
Spring. 4 credits. Prerequisites: CS 412 or permission of instructor.

CS 614(6410) Advanced Systems
Fall or spring. 4 credits. Prerequisite: CS 414 or permission of instructor.

[CS 615(6460) Peer-to-Peer Systems
Spring. 4 credits. Recommended: CS 614.]

[CS 619(6450) Research in Computer Networks (also CS 519[5450])
Fall or spring. 4 credits. Prerequisite: CS 419 or permission of instructor. Next offered 2008–2009.]

CS 621(6210) Matrix Computations
Fall. 4 credits. Prerequisites: MATH 411 and 431 or permission of instructor.

[CS 622(6220) Numerical Optimization and Nonlinear Algebraic Equations
Spring. 4 credits. Prerequisite: CS 621.]

[CS 624(6240) Numerical Solution of Differential Equations
Spring. 4 credits. Prerequisites: exposure to numerical analysis (e.g., CS 421 or 621), differential equations, and knowledge of MATLAB.]

[CS 626(6510) Computational Molecular Biology
Spring. 4 credits. Prerequisites: familiarity with linear programming, numerical solutions of ordinary differential equations, and nonlinear optimization methods.]

CS 628(6522) Biological Sequence Analysis
Fall. 4 credits. Prerequisite: none.

[CS 632(6320) Database Systems
Spring. 4 credits. Prerequisite: CS 432–433 or permission of instructor. Next offered 2008–2009.]

[CS 633(6322) Advanced Database Systems
Spring. 4 credits.]

CS 664(6670) Machine Vision
Fall or spring. 4 credits. Prerequisites: undergraduate-level understanding of algorithms and MATH 221 or equivalent. Offered spring 2008.

CS 665(6620) Advanced Interactive Graphics
Fall or spring. 4 credits. Prerequisites: CS 465 or equivalent and undergraduate-level understanding of algorithms, probability and statistics, vector calculus, and programming.

CS 667(6630) Physically Based Rendering
Fall or spring. 4 credits. Prerequisites: CS 465 or equivalent and undergraduate-level understanding of algorithms, programming, and vector calculus.

[CS 671(6762) Introduction to Automated Reasoning
Fall or spring. 4 credits. Prerequisite: CS 611 and graduate standing or permission of instructor.]

CS 672(6700) Advanced Artificial Intelligence
Spring. 4 credits. Prerequisites: CS 472 or permission of instructor.

[CS 673(6724) Integration of Artificial Intelligence and Operations Research
Spring. 3 credits.]

CS 674(6740) Advanced Language Technologies (also INFO 630[6300])
Fall or spring. 3 credits. Prerequisite: permission of instructor. Neither CS 430 nor CS 474 are prerequisites. Offered fall 2007.

CS 676(6764) Reasoning about Knowledge
Fall. 4 credits. Prerequisites: mathematical maturity and acquaintance with propositional logic.

[CS 677(6766) Reasoning about Uncertainty
Fall. 4 credits. Prerequisites: mathematical maturity and acquaintance with propositional logic. Next offered 2008–2009.]

CS 678(6780) Advanced Topics in Machine Learning
Fall or spring. 4 credits. Prerequisites: CS 478 or equivalent, or CS 578 or equivalent, or permission of instructor.

CS 681(6820) Analysis of Algorithms
Fall. 4 credits. Prerequisite: CS 482 or graduate standing.

CS 682(6810) Theory of Computing
Spring. 4 credits. Prerequisite: CS 381 and CS 482 or 681 or permission of instructor.

CS 683(6822) Advanced Design and Analysis of Algorithms
Spring. 4 credits. Prerequisite: CS 681 or permission of instructor.

CS 684(6840) Algorithmic Game Theory
Fall or spring. 4 credits. Prerequisite: background in algorithms and graphs at level of CS 482. No prior knowledge of game theory or economics assumed.

CS 685(6850) The Structure of Information Networks (also INFO 685[6850])
Fall or spring. 4 credits. Prerequisite: CS 482.

[CS 686(6860) Logics of Programs
Fall or spring. 4 credits. Prerequisites: CS 481, 682, and MATH 481 or MATH/CS 486. Next offered 2008–2009.]

CS 687(6830) Cryptography
Fall. 4 credits. Prerequisites: general ease with algorithms and elementary probability theory, maturity with mathematical proofs (ability to read and write mathematical proofs).

CS 709(7090) Computer Science Colloquium
Fall, spring. 1 credit. For staff, visitors, and graduate students interested in computer science. S-U grades only.

CS 714(7410) Topics in Systems
Fall or spring. 3 credits. Prerequisite: permission of instructor.

CS 715(7192) Seminar in Programming Refinement Logics
Fall, spring. 4 credits. Prerequisite: permission of instructor.

[CS 717(7430) Topics in Parallel Architectures
Fall. 4 credits. Prerequisite: CS 612 or permission of instructor.]

CS 718(7690) Computer Graphics Seminar
Fall, spring. 3 credits.

CS 719(7190) Seminar in Programming Languages
Fall, spring. 4 credits. Prerequisite: CS 611 or permission of instructor. S-U grades only.

CS 726(7590) Problems and Perspectives in Computational Molecular Biology
Fall or spring. 1 credit. Open to all from life sciences, computational sciences, and physical sciences. S-U grades only.

CS 732(7320) Topics in Database Systems
Fall, spring. 4 credits. S-U grades only.

CS 733(7390) Database Seminar
Spring. 1 credit. S-U grades only. Prerequisite: CS 633 or permission of instructor.

[CS 750(7726) Evolutionary Computation and Design Automation (also M&AE 650[6500])
Fall. 4 credits. Prerequisite: programming experience or permission of instructor. Next offered 2008–2009.]

CS 754(7490) Systems Research Seminar
Fall, spring. 1 credit. S-U grades only.

[CS 764(7670) Visual Object Recognition
Spring. 3 credits. Prerequisite: none.]

CS 772(7790) Seminar in Artificial Intelligence
Fall, spring. 4 credits. Prerequisite: permission of instructor. S-U grades only.

CS 775(7794) Seminar in Natural Language Understanding
Fall, spring. 2 credits.

[CS 785(7850) Seminar on Information Networks (also INFO 785[7850])
Fall. 4 credits. Prerequisite: CS 485 or 685 or permission of instructor.]

[CS 786(7860) Introduction to Kleene Algebra
Spring. 4 credits. Prerequisite: CS 381. Recommended: CS 482 or 681, CS 682, elementary logic (MATH 481 or 681), algebra (MATH 432).]

CS 789(7890) Seminar in Theory of Algorithms and Computing
Fall, spring. 4 credits. Prerequisite: permission of instructor. S-U grades only.

CS 790(7999) Independent Research
Fall, spring. Prerequisite: permission of computer science advisor.
Independent research or master of engineering project.

CS 990(9999) Thesis Research
Fall, spring. Prerequisite: permission of computer science advisor. S-U grades only.
Doctoral research.

EARTH AND ATMOSPHERIC SCIENCES

T. E. Jordan, chair; S. J. Colucci, co-chair (CALS); B. L. Isacks, director of undergraduate studies (Science of Earth Systems); R. W. Allmendinger, W. D. Allmon, C. Andronicos, M. Barazangi, L. D. Brown, L. M. Cathles, J. L. Cisne, K. H. Cook, A. T. DeGaetano, L. A. Derry, P. J. Gierasch, M. Goman, C. H. Greene, D. L. Hysell, R. W. Kay, S. Mahlburg Kay, M. C. Kelley, R. Lohman, N. Mahowald, B. Monger, A. Moore, J. Phipps Morgan, M. Pritchard, S. J. Riha, W. M. White, D. S. Wilks, M. W. Wysocki

For complete course descriptions, see the Earth and Atmospheric Sciences listing in the College of Arts and Sciences or College of Agriculture and Life Sciences section.

EAS 101(1101) Introductory Geological Sciences (To Know Earth)
Fall. 3 credits. C. Andronicos.

EAS 108(1108) Earth in the News
Summer. 3 credits. S. L. Losh.

EAS 109(1109) Dinosaurs
Fall. 1 credit. J. L. Cisne.

EAS 119(1190) Fossil Preparation
Fall. 1 credit. Prerequisite: EAS 109 or related EAS course. W. Allmon and J. Cisne.

EAS 122(1220) Earthquake! (also ENGRI 122[1120])
Spring. 3 credits. L. Brown.
Course in Introduction to Engineering series. For description, see ENGRI 122.

EAS 131(1310) Basic Principles of Meteorology
Fall. 3 credits. 1-credit lab is EAS 133. M. W. Wysocki.

EAS 133(1330) Basic Meteorology Lab
Fall. 1 credit. Corequisite: EAS 131. M. W. Wysocki.
Covers topics presented in EAS 131.

EAS 150(1500) Fortran Applications in Earth Science (also CIS 122[1122])
Spring. 2 credits, 7-week course. Prerequisite: CIS/EAS 121 or equivalent. Letter grades only. M. W. Wysocki.

EAS 154(1540) Introductory Oceanography (also BIOEE 154[1540])
Fall, summer. 3 credits. Lec. Optional 1-credit lab is EAS/BIOEE 155. Fall: B. Monger and C. Greene; summer: B. Monger.

EAS 155(1550) Introductory Oceanography Lab (also BIOEE 155[1500])
Fall. 1 credit. Lab. Corequisite: EAS/BIOEE 154. B. Monger and C. Greene.
Laboratory course covering topics presented in EAS/BIOEE 154.

EAS 170(1700) Evolution of the Earth and Life (also BIO G 170[1700])
Spring. 3 credits. J. L. Cisne.

EAS 213(2130) Marine and Coastal Geology
Summer. 4 credits. Prerequisite: introductory geology or ecology or permission of instructor. Staff.

EAS 220(2200) The Earth System
Fall, spring. 4 credits. Prerequisites: MATH 111/191. Letter grades only. Staff.

EAS 222(2220) Seminar—Hawaii's Environment
Fall. 1 credit. S-U grades only. A. Moore.

EAS 240(2400) Field Study of the Earth System
Spring. 5 credits. Prerequisites: enrollment in Earth and Environmental Sciences Semester in Hawaii; one semester of calculus (MATH 190, 191, 192, or 111, 112) and two semesters of any of the following: PHYS 207/208 or 112/213; CHEM 207/208; BIO G 101/103–102/104 or 105/106 or 109/110; or equivalent course work. A. Moore.

EAS 250(2500) Meteorological Observations and Instruments
Fall. 4 credits. Prerequisite: EAS 131. M. W. Wysocki and B. Monger.

EAS 268(2680) Climate and Global Warming
Spring. 3 credits. Prerequisite: basic college math. S-U or letter grades. A. T. DeGaetano.

EAS 296(2960) Forecast Competition
Fall and spring. 1 credit; students enroll for two consecutive semesters; credit awarded for second semester; may be repeated for credit. Prerequisite: sophomore standing in atmospheric science or permission of instructor. S-U grades only. D. S. Wilks.

EAS 301(3010) Evolution of the Earth System
Fall. 4 credits. Prerequisites: MATH 112 or 192 and CHEM 207 or equivalent, and EAS 220. T. Jordan, S. Riha, and W. D. Allmon. Four Saturday field trips.

EAS 303(3030) Introduction to Biogeochemistry (also NTRES 303[3030])
Fall. 4 credits. Prerequisites: CHEM 207, MATH 112, plus a biology and/or geology course. L. A. Derry and J. Yavitt.

EAS 304(3040) Interior of the Earth
Spring. 3 credits. Prerequisite: EAS 220 or permission of instructor. C. Andronicos.

EAS 305(3050) Climate Dynamics
Fall. 3 credits. Prerequisite: two semesters of calculus and one semester of physics. K. H. Cook.

EAS 322(3220) Biogeochemistry of the Hawaiian Islands
Spring. 4 credits. Prerequisite: enrollment in EES semester in Hawaii, EAS 220, EAS 303, or permission of instructor. L. Derry.

EAS 334(3340) Microclimatology
Spring. 3 credits. Prerequisite: physics course. Offered alternate years. D. S. Wilks.

EAS 341(3410) Atmospheric Thermodynamics and Hydrostatics
Fall. 3 credits. Prerequisites: one year of calculus and one semester of physics. M. W. Wysocki.

EAS 342(3420) Atmospheric Dynamics
Spring. 3 credits. Prerequisites: MATH 192, 213 or equivalent; one year physics. K. H. Cook.

EAS 350(3500) Dynamics of Marine Ecosystems (also BIOEE 350[3500])
Fall. 3 credits. Prerequisites: one year of calculus and a semester of oceanography (e.g., EAS 154), or permission of instructor. Offered alternate years. C. H. Greene and R. W. Howarth.

EAS 351(3510) Marine Ecosystems Field Course (BIOEE 351[3510])
Spring. 4 credits. Recommended: EAS 240. C. H. Greene, C. D. Harvell, and B. Monger.

EAS 352(3520) Synoptic Meteorology I
Spring. 3 credits. Prerequisite: EAS 341. Corequisite: EAS 342. M. W. Wysocki.

[EAS 353(3530) Physical Oceanography
Fall. 3 credits. Prerequisites: MATH 112 or 192, or one year of physics, or permission of instructor. Next offered 2008–2009. B. C. Monger.]

EAS 401(4010) Fundamentals of Energy and Mineral Resources
Fall. 3 credits. Prerequisites: introductory college-level geology, physics, and chemistry and math through differential equations or permission of instructor. L. Cathles.

[EAS 404(4040) Geodynamics
Spring. 3 credits. Prerequisite: calculus and calculus-based physics course or permission of instructor. Offered alternate years; next offered 2008–2009. J. Phipps Morgan.]

EAS 405(4050) Active Tectonics
Spring. 3 credits. Recommended: mechanical background equivalent to EAS 426/488. S-U or letter grades. Offered alternate years. R. Lohman.

EAS 415(4150) Geomorphology
Fall. 3 credits. B. L. Isacks.

EAS 417(4170) Field Mapping in Argentina
Summer. 3 credits. Prerequisites: introductory EAS course and EAS 426 or EAS 304. S. Mahlburg Kay.

[EAS 425(4250) European Discovery of Impacts and Explosive Volcanism
Spring. 2 credits. Prerequisite: junior, senior, or graduate students with background in geology and permission of instructor. One two-hour meeting per week plus field trip during spring break. Offered alternate years; next offered 2008–2009. J. Phipps Morgan.]

EAS 426(4260) Structural Geology
Spring. 4 credits. Prerequisite: one semester of calculus plus an introductory geology course or permission of instructor. One weekend field trip. Offered alternate years. R. W. Allmendinger.

[EAS 434(4340) Exploration Geophysics
Fall. 3 credits. Prerequisites: MATH 192 and PHYS 208, 213, or equivalent. Offered alternate years; next offered 2008–2009. L. D. Brown.]

EAS 435(4350) Statistical Methods in Meteorology and Climatology
Fall. 3 credits. Prerequisites: introductory statistics (e.g., AEM 210) and calculus course. D. S. Wilks.

EAS 437(4370) Geophysical Field Methods (also ARKEO 437[4370])
Fall. 3 credits. Prerequisite: PHYS 213 or 208 or permission of instructor. Offered alternate years. L. D. Brown.

EAS 440(4400) Seminar on the Intergovernmental Panel on Climate Change Report
Fall. 2 credits. Prerequisites: senior or higher standing. Offered alternate years. N. Mahowald.

EAS 447(4470) Physical Meteorology
Fall. 3 credits. Prerequisites: one year each of calculus and physics. Offered alternate years. A. T. DeGaetano.

EAS 451(4510) Synoptic Meteorology II
Fall. 3 credits. Prerequisites: EAS 341 and 342. E. K. Vizy.

EAS 453(4530) Mineralogy
Fall. 4 credits. Prerequisites: EAS 101 or 220 and CHEM 207/211 or permission of instructor. S. Mahlburg Kay.

[EAS 454(4540) Petrology and Geochemistry
Spring. 4 credits. Prerequisite: EAS 453. Next offered 2008–2009. R. W. Kay.]

EAS 455(4550) Geochemistry
Fall. 4 credits. Prerequisites: CHEM 207 and MATH 192 or equivalent. Recommended: EAS 304. Offered alternate years. W. M. White.

EAS 456(4560) Mesoscale Meteorology
Spring. 3 credits. Prerequisites: EAS 341 and 342 or permission of instructor. S. J. Colucci.

[EAS 457(4570) Atmospheric Air Pollution
Fall. 3 credits. Prerequisites: EAS 341 or thermodynamics course, and one semester of chemistry, or permission of instructor. Next offered 2008–2009. M. W. Wysocki.]

[EAS 458(4580) Volcanology
Fall. 3 credits. Prerequisite: EAS 304 or equivalent. Offered alternate years; next offered 2008–2009. R. W. Kay.]

[EAS 460(4600) Late Quaternary Paleoecology
Fall. 4 credits. Offered alternate years; next offered 2008–2009. M. Goman.]

EAS 461(4610) Paleoclimate: Since the Last Ice Age
Fall. 3 credits. Prerequisite: EAS 220 or permission of instructor. Offered alternate years. M. Goman.

[EAS 462(4620) Marine Ecology (also BIOEE 462[4620])
Fall. 3 credits. Limited to 75 students. Prerequisite: BIOEE 261. Offered alternate years; next offered 2008–2009. C. D. Harvell and C. H. Greene.]

EAS 470(4700) Weather Forecasting and Analysis
Spring. 3 credits. Prerequisites: EAS 352 and 451. M. W. Wysocki.

EAS 471(4710) Introduction to Groundwater Hydrology (also BEE 471[4710])
Spring. 3 credits. Prerequisites: MATH 294 and ENGRD 202. Offered alternate years. L. Cathles and T. Steenhuis.

EAS 475(4750) Special Topics in Oceanography
Fall, spring, summer. 2–6 credits, variable. Prerequisites: one semester of oceanography and permission of instructor. Fall, spring: C. H. Greene; summer: B. C. Monger.

EAS 476(4760) Sedimentary Basins
Spring. 3 credits. Prerequisite: EAS 301 or permission of instructor. Offered alternate years. T. E. Jordan.

[EAS 478(4780) Stratigraphy
Fall. 3 credits. Prerequisite: EAS 301 or permission of instructor. Offered alternate years; next offered 2008–2009. T. E. Jordan.]

EAS 479(4790) Paleobiology (also BIOEE 479[4790])
Spring. 4 credits. Prerequisites: one year introductory biology and either BIOEE 274 or 373 or EAS 301, or permission of instructor. Offered alternate years. W. Allmon.

EAS 481(4810) Senior Survey of Earth Systems
Spring, fall. 2 credits. Fall, R. Kay; spring, J. Cisne.

EAS 483(4830) Environmental Biophysics (also CSS 483[4830])
Spring. 3 credits. Prerequisite: CSS 260 or equivalent or permission of instructor. Offered alternate years. S. J. Riha.

EAS 484(4840) Inverse Methods in the Natural Sciences
Spring. 3 credits. Prerequisite: MATH 294. D. Hysell.

EAS 487(4870) Introduction to Radar and Remote Sensing (also ECE 487[4870])
Fall. 3 credits. Prerequisites: PHYS 208 or 213 or equivalent or permission of instructor. D. L. Hysell.

EAS 488(4880) Geophysics and Geotectonics
Spring. 3 credits. Prerequisites: MATH 192 (or 112) and PHYS 208 or 213. Offered alternate years. M. Pritchard.

EAS 491–492(4910–4920) Undergraduate Research
Fall, spring. 1–4 credits. Students must complete form at 2124 Snee Hall. Staff (B. L. Isacks, coordinator).

EAS 494(4940) Special Topics in Atmospheric Science
Fall, spring. 8 credits max. Undergraduate level. S-U or letter grades. Staff.

EAS 496(4960) Internship Experience
Fall, spring. 2 credits. Prerequisite: EAS 240. S-U grades only. A. Moore.

EAS 497(4970) Individual Study in Atmospheric Science
Fall, spring. 1–6 credits. Students must register using independent study form. S-U grades only. Staff.

EAS 498(4980) Teaching Experience in Earth and Atmospheric Sciences
Fall, spring. 1–4 credits. Students must register using independent study form. S-U grades only. Staff.

EAS 499(4990) Undergraduate Research in Atmospheric Science
Fall, spring. Credit TBA. Students must register using independent study form. S-U grades only. Staff.

[EAS 500(5000) Design Project in Geohydrology
Fall, spring. 3–12 credits. Alternative to industrial project for M.Eng. students choosing geohydrology option. May continue over two or more semesters. Next offered 2008–2009. L. M. Cathles.]

[EAS 502(5020) Case Histories in Groundwater Analysis
Spring. 4 credits. Next offered 2008–2009. L. M. Cathles.]

EAS 505(5050) Fluid Dynamics in the Earth Sciences
Spring. 3 credits. Prerequisites: MATH through 294, PHYS through 208/214 or permission of instructor. L. Cathles and M. Wysocki.

[EAS 522(5220) Advanced Structural Geology I
Fall. 3 credits. Prerequisites: EAS 426 and permission of instructor. Offered alternate years; next offered 2008–2009. R. W. Allmendinger and C. Andronicos.]

EAS 524(5240) Advanced Structural Geology II
Fall. 3 credits. Prerequisites: EAS 426 and permission of instructor. Offered alternate years; R. W. Allmendinger.

EAS 542(5420) Numerical Methods in Atmospheric Modeling
Spring. 3 credits. Prerequisites: partial differential equations and introductory numerical methods or permission of instructor. S-U or letter grades. N. Mahowald.

EAS 553(5530) Advanced Petrology
Fall. 3 credits. Prerequisite: EAS 454. Offered alternate years. R. W. Kay.

[EAS 575(5750) Planetary Atmospheres (also ASTRO 575[6575])
Fall. 4 credits. Prerequisites: undergraduate physics, vector calculus. Offered alternate years; next offered 2008–2009. P. Gierasch.]

[EAS 577(5770) Planetary Surface Processes (also ASTRO 577[6577])
Spring. 3 or 4 credits. Offered alternate years; next offered 2008–2009. J. Bell.]

[EAS 578(5780) Planet Formation and Evolution (also ASTRO 578[6578])
Fall. 4 credits. Prerequisites: familiarity with elementary physics and math or permission of instructor. Offered alternate years; next offered 2008–2009. J-L. Margot and M. Pritchard.]

EAS 584(5840) Inverse Methods in the Natural Sciences
Spring. 3 credits. Prerequisite: MATH 294. Complete substantial class project. D. Hysell.

[EAS 628(6280) Geology of Orogenic Belts
Spring. 3 credits. Prerequisite: permission of instructor. Next offered 2008–2009. S. M. Kay.]

[EAS 641(6410) Analysis of Biogeochemical Systems
Spring. 3 credits. Prerequisite: MATH 293 or permission of instructor. Offered alternate years; next offered 2008–2009. L. A. Derry.]

EAS 648(6480) Air Quality and Atmospheric Chemistry (also M&AE 648[6480])
Fall. 3 credits. Prerequisites: first-year chemistry and thermodynamics (or equivalent) and fluid mechanics (or equivalent); graduate standing or permission of instructor. S-U or letter grades. K. M. Zhang.
For description, see M&AE 648.

[EAS 652(6520) Advanced Atmospheric Dynamics (also ASTRO 652[7652])
Spring. 3 credits. Prerequisites: EAS 341 and 342 or equivalent. Offered alternate years; next offered 2008–2009. S. J. Colucci.]

[EAS 656(6560) Isotope Geochemistry
Spring. 3 credits. Open to undergraduates. Prerequisite: EAS 455 or permission of instructor. Offered alternate years; next offered 2008–2009. W. M. White.]

[EAS 666(6660) Applied Multivariate Statistics
Spring. 3 credits. Prerequisites: multivariate calculus, matrix algebra, and two statistics courses. Offered alternate years; next offered 2008–2009. D. S. Wilks.]

[EAS 675(6750) Modeling the Soil-Plant-Atmosphere System (also CSS 675[6750])
Spring. 3 credits. Prerequisite: EAS/CSS 483 or equivalent. Next offered 2008–2009. S. J. Riha.]

EAS 692(6920) Special Topics in Atmospheric Science
Fall, spring. 1–6 credits. S-U or letter grades. Staff.

EAS 693(6930) Special Topics in Geological Sciences
Fall or spring. 1–3 credits, variable. S-U or letter grades. Staff.

EAS 700–799(7000–7990) Seminars and Special Work
Fall, spring. 1–3 credits. Prerequisite: permission of instructor. Staff.

EAS 701–702(7010–7020) Thesis Research
701, fall; 702, spring. 1–15 credits, variable. S-U or letter grades. Staff.

EAS 711(7110) Upper Atmospheric and Space Physics
Fall or spring. 1–6 credits. D. L. Hysell. Seminar.

EAS 722(7220) Advanced Topics in Structural Geology
R. W. Allmendinger.

EAS 731(7310) Advanced Topics in Remote Sensing and Geophysics
M. Pritchard.

EAS 733(7330) Advanced Topics in Geodynamics
Spring. J. Phipps Morgan.

EAS 750(7500) Satellite Remote Sensing in Biological Oceanography
Summer. 3 credits. B. C. Monger.

EAS 751(7510) Petrology and Geochemistry
R. W. Kay.

EAS 755(7550) Advanced Topics in Tectonics and Geochemistry
Fall. 3 credits. J. Phipps Morgan.

EAS 757(7570) Current Research in Petrology and Geochemistry
S. Mahlburg Kay.

EAS 762(7620) Advanced Topics in Paleobiology
W. D. Allmon.

EAS 771(7710) Advanced Topics in Sedimentology and Stratigraphy
T. E. Jordan.

EAS 773(7730) Paleobiology
J. L. Cisne.

EAS 775(7750) Advanced Topics in Oceanography
C. H. Greene.

EAS 780(7800) Earthquake Record Reading
Fall. M. Barazangi.

EAS 781(7810) Exploration Geophysics
L. D. Brown.

EAS 793(7930) Andes-Himalaya Seminar
S. Mahlburg Kay, R. W. Allmendinger, B. L. Isacks, and T. E. Jordan.

EAS 795(7950) Low-Temperature Geochemistry
1–3 credits. S-U grades only. L. A. Derry.

EAS 796(7960) Geochemistry of the Solid Earth
W. M. White.

EAS 797(7970) Fluid-Rock Interactions
L. M. Cathles.

EAS 799(7990) Soil, Water, and Geology Seminar
Spring. L. M. Cathles and T. S. Steenhuis.

EAS 850(8500) Master's-Level Thesis Research in Atmospheric Science
Fall, spring. Credit. S-U grades only. Graduate faculty.

EAS 950(9500) Graduate-Level Dissertation Research in Atmospheric Science
Fall, spring. Credit. S-U or letter grades. Graduate faculty.

EAS 951(9510) Doctoral-Level Dissertation Research in Atmospheric Science
Fall, spring. Credit. S-U or letter grades. Graduate faculty.

ELECTRICAL AND COMPUTER ENGINEERING

C. R. Pollock, Director; E. Afshari; D. F. Delchamps, Advising Coordinator; D. H. Albonesi, A. B. Apsel, S. Bhave, A. W. Bojanczyk, M. Burtscher, H.-D. Chiang, L. F. Eastman, T. L. Fine, W. K. Fuchs, Z. J. Haas, D. A. Hammer, S. S. Hemami, C. R. Johnson, Jr., E. Kan, M. C. Kelley, P. M. Kintner, R. R. Kline, A. Lal, M. Lipson, R. Manohar, J. F. Martínez, S. A. McKee, T. W. Parks, F. Rana, A. P. Reeves, A. Scaglione, S. Servetto, C. E. Seyler, J. R. Shealy, M. G. Spencer, G. E. Suh, C. L. Tang, R. J. Thomas, S. Tiwari, L. Tong, A. B. Wagner, S. B. Wicker

ECE 210(2100) Introduction to Circuits for Electrical and Computer Engineers (also ENGRD 210[2100])
Fall, spring. 4 credits. Corequisites: MATH 293 and PHYS 213. All students must enroll in a lab and a sec.
For description, see ENGRD 210.

ECE 220(2200) Signals and Information
Fall, spring. 4 credits. Prerequisite: MATH 293. All students must enroll in a lab and a sec.
Introduction to signal processing. Topics include frequency-based representations: Fourier series and discrete Fourier transform; discrete time linear systems: input/output relationships, filtering, spectral response; analog-to-digital and digital-to-analog conversion; continuous time signals and linear time invariant systems: frequency response and continuous-time Fourier transform.

ECE 230(2300) Introduction to Digital Logic Design (also ENGRD 230[2300])
Fall, spring. 4 credits. Prerequisite: CS 100.
For description, see ENGRD 230.

[ECE 250(2500) Technology in Society (also ENGRG 250[2500], HIST/S&TS 250[2500])
Fall. 3 credits. Humanities elective for engineering students. Next offered 2008–2009.
For description, see ENGRG 250.]

ECE 291–292(2910–2920) Sophomore Electrical and Computer Engineering Independent Project
Fall, 291; spring, 292. 1–8 credits.
Individual study or directed reading in connection with a special engineering problem chosen by the student, after consultation with the faculty member directing the project. An engineering report on the project is required. Students must make individual arrangements with a faculty sponsor and submit an Independent Project Form to the Student Services Office, 223 Phillips Hall.

ECE 293–294(2930–2940) Sophomore Electrical and Computer Engineering Group Projects

Fall, 293; spring, 294. 1–8 credits.

Group study, analysis, and, usually, experimental tests in connection with a special engineering project chosen by the students after consultation with the faculty member directing the project. New projects will be added upon faculty request. Written progress reports are required. Students must submit a Group Project Form to the Student Services Office, 223 Phillips Hall.

[ECE 298(2980) Inventing an Information Society (also AM ST 292[2980], HIST 292[2920], S&TS 292[2921], ENGRG 298[2980], INFO 292[2921])

Spring. 3 credits. Approved for humanities distribution. Next offered 2008–2009.

For description, see ENGRG 298.]

ECE 303(3030) Electromagnetic Fields and Waves

Fall. 4 credits. Prerequisites: grade of C or better in: PHYS 213, PHYS 214, MATH 293, MATH 294, and ECE/ENGRD 210.

Covers static, quasi-static, and dynamic electromagnetic fields and waves. Topics include Maxwell's equations (integral and differential forms), fields of charge and current distributions, boundary conditions, fields near conductors, method of images, material polarization and dielectrics; energy, work, and power in electromagnetic systems; wave propagation and polarization, waves in media (dielectrics, conductors, and anisotropic materials); reflection, transmission, and refraction at media interfaces; guided waves in transmission lines, Smith charts, transients; metallic and dielectric waveguides; radiation and antennas, antenna arrays, electric circuits for transmission and reception, aperture antennas and diffraction.

[ECE 304(3040) Computational Electronics, Electrodynamics, and Devices

Spring. 3 credits. Prerequisite: ECE 303. Co-meets with ECE 504. Next offered 2008–2009.

Methods of computational electromagnetics are introduced in conjunction with and shown to supplement analytic solution methods. Topics include a review of vector calculus and electromagnetic theory, finite difference methods for electrostatics and wave propagation in one or more dimensions, finite difference time domain methods, finite element methods in one and two dimensions, integral formulations of Maxwell's equations, the method of moments, and Green's functions and numerical integration. Applications are drawn from microwave circuits and microwave cavities, magnetostatics and eddy current problems, capacitance calculations, scattering from thin wires, and optical components.]

ECE 306(3060) Fundamentals of Quantum and Solid-State Electronics

Spring. 4 credits. Prerequisites: PHYS 214 and MATH 294.

Introductory quantum mechanics and solid-state physics necessary for modern solid-state electronic devices. Topics include the formalism and methods of quantum mechanics, the hydrogen atom, the structure of simple solids, energy bands, Fermi-Dirac statistics, and the basic physics of semiconductors. Applications include quantum wells and the p-n junction.

ECE 310(3100) Introduction to Probability and Random Signals

Spring. 4 credits. Prerequisite: MATH 294. May be used in place of ENGRD 270 to satisfy engineering distribution requirement.

Introduction to the theory of probability as a basis for modeling random phenomena and signals, calculating the response of systems, and making estimates, inferences, and decisions in the presence of chance and uncertainty. Applications are given in such areas as communications, device modeling, and information theory. Material includes: classical probability, probability measures, countable and uncountable sample spaces, random variables, probability mass function, probability density function, cumulative distribution function, important discrete and continuous distributions, functions of one random variable, functions of two random variables, random multivariate functions, moments, independence and correlation, conditional probability, characteristic functions, special characteristics of Normal distribution, signals and filtering, Central Limit Theorem, Law of Large Numbers, introduction to Decision and Estimation.

ECE 311(3110) Electrical and Computer Engineering Honors Seminar

Spring. 1 or 2 credits.

Students are required to attend all the lectures. Honors students must take this seminar for letter grade and 2 credits. Two summary papers are required. Nonhonors students must take the seminar pass/fail and for 1 credit. One summary paper is required. Summary papers review a topic presented in the seminar.

ECE 314(3140) Computer Organization (also CS 314[3420])

Spring. 4 credits. Prerequisite: CS/ENGRD 211 or ENGRD 230.

Topics include performance metrics, data formats, instruction sets, addressing modes, computer arithmetic, microcoded and pipelined datapath design, memory hierarchies including caches and virtual memory, I/O devices, bus-based I/O systems. Students learn assembly language programming and design a simple pipelined processor.

ECE 315(3150) Introduction to Microelectronics

Fall, spring. 4 credits. Prerequisite: ECE/ENGRD 210.

The course offers an introduction to the basic devices and circuits in modern microelectronics. Students will learn not only basic structures and operations of semiconductor devices through simple models (diodes, CMOS and BJT), but also how to analyze and design basic transistor modules in digital and analog circuits including biasing, amplifiers, filters, logic gates, and memory. We will introduce intuitive design methods to map circuit specifications to transistor topology, as well as first-order time-constant estimation. SPICE and measurement labs will accompany the progress in lectures for hands-on experiences.

ECE 320(3200) Networks and Systems

Spring. 4 credits. Prerequisites: ECE 220 and MATH 294.

Students develop a working understanding of the analytical and computational tools used in the design and representation of complex networks and systems. Topics include state-space techniques, finite state machines, graph-theoretic approaches to network design and analysis, complexity, phase transitions in complex systems, and scalability.

ECE 325(3250) Foundations of ECE Mathematics

Fall. 3 credits. Prerequisites: MATH 293 and MATH 294.

Course aims to deepen students' working knowledge of mathematical tools relevant to ECE applications. While the course emphasizes fundamentals, it also provides an ECE context for the topics it covers, which include foundational material about sets and functions; linear algebra; inner products and orthogonal representations; basic ideas from multivariable calculus; and elementary convex analysis.

ECE 391–392(3910–3920) Junior Electrical and Computer Engineering Independent Project

Fall, 391; spring, 392. 1–8 credits.

For description, see ECE 291–292.

ECE 393–394(3930–3940) Junior Electrical and Computer Engineering Group Project

Fall, 393; spring, 394. 1–8 credits.

For description, see ECE 293–294.

ECE 402(4020) Biomedical System Design (also BME 404[4040])

Spring. 4 credits. Culminating design experience (CDE) course. Co- or prerequisites: at least one of: ECE 425, 476, 453.

Introduces techniques of measuring and conditioning low-level (biological) signals. Topics include special signal to noise improvement circuits for analog signals, techniques to remove common-mode and correlated noise, and computer-aided techniques for analyzing sampled data. Final six or seven weeks devoted to designing/prototyping a safe and effective "ambulatory microprocessor-controlled blood pressure monitor." Formal design document is required.

ECE 411(4110) Random Signals in Communications and Signal Processing

Fall. 4 credits. Prerequisite: ECE 220 and ECE 310 or equivalent.

Introduction to models for random signals in discrete and continuous time; Markov chains, Poisson process, queuing processes, power spectral densities, Gaussian random process. Response of linear systems to random signals. Elements of estimation and inference as they arise in communications and digital signal processing systems.

ECE 413(4130) Introduction to Nuclear Science and Engineering (also M&AE 458[4580], T&AM 413[4130])

Fall. 3 credits. Prerequisites: PHYS 214 and MATH 294.

For description, see T&AM 413.

ECE 415(4150) GPS: Theory and Design (also M&AE 415[4150])

Fall. 4 credits. Culminating design experience (CDE) course. Prerequisite: a 300-level engineering course with advanced math content (e.g., ECE 303 or M&AE 326).

Analysis of GPS operating principles and engineering practice with a culminating design exercise. Navigational algorithms, receiver analysis, error investigation, dilution of precision, antennas, differential GPS.

ECE 425(4250) Digital Signal Processing
Fall. 4 credits. Prerequisites: ECE 220 and 310.
Introduces statistical signal processing. Signal representation and manipulation are covered via correlation and using the DFT/FFT to estimate other transforms; applications of these topics are then covered, including quantization, quantization effects in digital filters, multirate DSP, filter banks, delta-sigma modulation, power spectrum estimation, and introductions to Wiener and Kalman filtering and image processing.

ECE 426(4260) Applications of Signal Processing
Spring. 4 credits. Culminating Design Experience (CDE) course. Prerequisite: ECE 425 or permission of instructor.
Applications of signal processing, including signal analysis, filtering, and signal synthesis. The course is laboratory oriented, emphasizing individual student projects. Design is done with signal-processing hardware and by computer simulation. Topics include filter design, spectral analysis, speech coding, speech processing, digital recording, adaptive noise cancellation, and digital signal synthesis.

ECE 430(4300) Lasers and Optical Electronics
Fall. 4 credits. Prerequisite: ECE 303 or equivalent.
Introduction to the operation and application of lasers. Cover diffraction-limited optics, Gaussian beams, optical resonators, interaction of radiation with matter, physics of laser operation, and laser design. Discusses applications of coherent radiation to nonlinear optics, communication, and research.

ECE 432(4320) MicroElectro Mechanical Systems (MEMS)
Fall. 4 credits. Prerequisite: ECE 315 or permission of instructor.
Introduction to MEMS: microsensors, microactuators, and microrobots. Fundamentals of MEMS, including materials, microstructures, devices and simple microelectro-mechanical systems, scaling electronic and mechanical systems to the micrometer/nm-scale, material issues, and the integration of micromechanical structures and actuators with simple electronics. This is an interdisciplinary course drawing content from mechanics, materials, structures, electronic systems, and the disciplines of physics and chemistry.

ECE 433(4320) Microwave Theory, Devices, and Applications
Fall. 4 credits. Prerequisite: ECE 303.
Introduction to the properties of microwave devices and their applications in circuits, waveguides, resonators, and antennas. The course will cover the considerations that must be appreciated when the operating frequency approaches or exceeds 1GHz. Topics include microwave devices, microwave measurement techniques, S-parameters, signal flow diagrams, matching networks, basic circuit design considerations, and computer-aided device and circuit analysis. The course emphasizes physical understanding and intuitive design methods. Labs cover basic measurement techniques for active and passive elements as well as low noise amplifier design.

ECE 437(4370) Fiber and Integrated Optics
Spring. 4 credits. Culminating design experience (CDE) course. Prerequisite: ECE 303 or equivalent.
Physical principles of optical waveguides. Wave equation solutions to the mode structure in waveguides, numerical analysis, mode coupling, dispersion and bandwidth limitations, optical materials, photonic band gap structures. Project design of planar optical components.

ECE 445(4450) Computer Networks and Telecommunications
Fall. 4 credits. Prerequisites: ECE or CS 314 and a course in probability.
Design, analysis, and implementation of computer and communication networks and systems. This is a basic course in networking. Examples of topics that are covered include data transmission and data encoding, data link control, circuit vs. packet switching, Asynchronous Transfer Mode, local area network technology, network interconnections, protocol design (OSE and IP), network security, and multimedia. Emphasis is placed on performance evaluation.

[ECE 446(4460) Digital Communications Over Packet-Switched Networks
Spring. 4 credits. Culminating design experience (CDE) course. Prerequisites: ECE/CS 314 and probability course. Next offered 2008–2009.
Basic course in networking covering the design and performance analysis of communication systems operating over packet-switched networks. Aims to bridge the gap between a classical networking course and a classical digital communications course. The course is lab oriented, with a strong emphasis on programming assignments (both C and MATLAB). Topics include data compression, error control in networks, and network algorithms.]

ECE 451(4510) Electric Power Systems I
Fall. 4 credits. Prerequisite: ECE 320 or equivalent.
Acquaints students with modern electric power system analysis and control. Stresses analysis techniques appropriate for the restructured industry and advanced protection and control systems. Topics include transmission line models, transformers and per unit system, generator models, network matrices, power flow, system protection, computer relaying, and GPS-based measurement and control systems.

ECE 452(4520) Electric Power Systems II
Spring. 4 credits. Prerequisite: ECE 320 or permission of instructor.
Acquaints students with modern electric power system operation and control. Explores aspects of the restructuring of the industry and its implications for planning and operation objectives and methods. Topics include unit commitment, economic dispatch, optimal power flow, control of generation, system security and reliability, state-estimation, analysis of system dynamics, and system protection.

ECE 453(4530) Analog Integrated Circuit Design
Fall. 4 credits. Culminating design experience (CDE) course. Prerequisite: ECE 315 or equivalent.
Overview of devices available to analog integrated-circuit designers in modern CMOS and BiCMOS processes: resistors, capacitors, MOS transistors, and bipolar transistors. Basic building blocks for linear analog integrated circuits: single-stage amplifiers, current mirrors, and differential pairs. Transistor-level design of linear analog integrated circuits, such as operational amplifiers and operational transconductance amplifiers. Layout techniques for analog integrated circuits. Throughout the course, emphasis is placed on design-oriented analysis techniques.

ECE 457(4570) Silicon Device Fundamentals
Spring. 4 credits. Prerequisites: ECE 315 and 306 or MS&E 262 or A&EP 450.
The course teaches fundamental principles on semiconductor carrier statistics, band diagrams, pn-junction diodes, heterojunctions, Schottky diodes, BJT, MOS capacitor and MOSFET. Emphasis is put on the MOSFET designs for advanced VLSI technology from its physical structure, accurate modeling, maufacturability and applications. Device designs will include short channel effects, gate-stack alternatives, band engineering, and strain engineering. By using computer simulation and experimental data, the course will culminate in a design project dealing with technical concerns in current VLSI industry. The goal for this course is to train circuit, device, and process engineers for semiconductor technology research and development.

ECE 467(4670) Digital Communication Receiver Design
Fall. 4 credits. Culminating design experience (CDE) course. Prerequisite: ECE 220.
Introduction to broadband digital receiver design. Topics include PAM and QAM modulation and down-conversion, pulse-shaping, matched filtering, carrier frequency and phase recovery, baud-timing synchronization, packet marker synchronization, adaptive linear equalization, and coding. Course project: composition and testing of a MATLAB–based software receiver.

ECE 468(4680) Telecommunication Systems
Spring. 4 credits. Prerequisite: ECE 467 or permission of instructor. Recommended: ECE 411.
Quadrature amplitude modulation receiver design, including I/Q mismatch compensation, carrier recovery (using Costas loop and phase-locked loop), baud-timing (using bandedge power optimization), and adaptive equalization (trained, blind, fractionally spaced, and using decision-feedback).

ECE 472(4720) Feedback Control Systems (also CHEME 472[4720], M&AE 478[4780])
Fall, spring. 4 credits. Prerequisites: CHEME 372, ECE 220, M&AE 326, or permission of instructor.
For description, see M&AE 478.

[ECE 473(4730) Optimizing Compilers
Fall. 4 credits. Prerequisite: ECE 314/CS 314. Next offered 2008–2009.
Covers compiler optimizations for high-performance microprocessors as well as how software interacts with hardware and the operating system. The projects involve implementing, testing, and evaluating an optimizing compiler backend that generates executables for a UNIX workstation. Lecture topics include three-address code, static single assignment form, many code optimizations,

code tuning case studies, feedback optimizations, machine instruction formats, system calls, and executable formats.]

ECE 474(4740) Digital VLSI Design

Spring. 4 credits. Prerequisites: ECE/ENGRD 230, ECE/CS 314.

Introduction to digital VLSI design. Topics include basic transistor physics, switching networks and transistors, combinational and sequential logic, latches, clocking strategies, domino logic, PLAs, memories, physical design, floor planning, CMOS scaling, and performance and power considerations, etc. Lecture and homework topics emphasize disciplined design, and include: CMOS logic, layout, and timing; computer-aided design and analysis tools; and electrical and performance considerations.

ECE 475(4750) Computer Architecture (also CS 416[4420])

Fall. 4 credits. Culminating design experience (CDE) course. Prerequisites: ENGRD 230 and ECE 314/CS 314.

Topics include instruction set principles, advanced pipelining, data and control hazards, multi-cycle instructions, dynamic scheduling, out-of-order execution, speculation branch prediction, instruction-level parallelism, and high-performance memory hierarchies. Students learn the issues and trade-offs involved in the design of modern microprocessors. Labs involve the design of a processor and cache subsystem at the RTL level.

ECE 476(4760) Digital Systems Design Using Microcontrollers

Spring. 4 credits. Culminating design experience (CDE) course. Prerequisite: ECE 314/CS 314. ECE 315 is highly recommended.

Design of real-time digital systems using microprocessor-based embedded controllers. Students working in pairs design, debug, and construct several small systems that illustrate and employ the techniques of digital system design acquired in previous courses. The content focuses on the laboratory work. The lectures are used primarily for the introduction of examples, description of specific modules to be designed, and instruction in the hardware and high-level design tools to be employed.

ECE 482(4820) Plasma Processing of Electronic Materials (also MS&E 482[4820])

Spring. 3 credits. Prerequisites: PHYS 213 and 214 or equivalents. Offered if sufficient demand.

Fundamental principles that govern partially ionized, chemically reactive plasma discharges and their applications to processing electronic materials. Topics include simple models of low pressure, partially ionized plasmas, collision phenomena, diffusive processes, plasma chemistry and surface processes. Examples and their applications to electronic materials processing are discussed in detail.

ECE 484(4840) Introduction to Controlled Fusion: Principles and Technology (also M&AE 459[4590], NS&E 484[4840])

Spring. 3 credits. Prerequisites: PHYS 112, 213, and 214, or equivalent background in electricity and magnetism and mechanics. Intended for seniors and graduate students in engineering and physical sciences.

Introduction to the physical principles and various engineering aspects underlying power generation by controlled fusion. Topics include: fuels and conditions required for fusion power and basic fusion-reactor concepts; fundamental aspects of plasma physics relevant to fusion plasmas and basic engineering problems for a fusion reactor; and an engineering analysis of proposed magnetic and/or intertial confinement fusion-reactor designs.

ECE 487(4870) Introduction to Radar and Remote Sensing (also EAS 487[4870])

Fall. 3 credits. Prerequisites: ECE 220 and 486 (or grade of B or better in ECE 303).

For description, see EAS 487 in the College of Arts and Sciences.

ECE 488(4880) Radio Frequency (RF) Circuits and Systems

Spring. 4 credits. Prerequisite: ECE 315 or equivalent.

Basic RF circuits and applications. Receivers, transmitters, modulators, filters, detectors, transmission lines, oscillators, frequency synthesizers, low-noise amplifiers. Applications include communication systems, radio and television broadcasting, radar, radio, and radar astronomy. Computer-aided circuit analysis. Six laboratory sessions.

ECE 491–492(4910–4920) Senior Electrical and Computer Independent Engineering Project

Fall, 491; spring, 492. 1–8 credits.

For description, see ECE 291–292.

ECE 493–494(4930–4940) Senior Electrical and Computer Engineering Group Project

Fall, 493; spring, 494. 1–8 credits.

For description, see ECE 293-294.

ECE 495–499(4950–4990) Special Topics in Electrical and Computer Engineering

Spring, fall. 1–4 credits.

Seminar, special interest, or temporary course.

[ECE 504(5040) Advanced Computational Electronics, Electrodynamics, and Devices

Spring. 3 credits. Prerequisite: ECE 303. Co-meets with ECE 304. Next offered 2008–2009.

For description, see ECE 304. Students taking ECE 504 will be expected to complete and present a substantial class project to be negotiated with the instructor.]

ECE 512(5120) Applied Systems Engineering I (also CEE 504[5040], CS 504[5040], M&AE 591[5910], OR&IE 512[5120], SYSEN 510[5100])

Fall. 3 credits. Prerequisites: senior or graduate standing in engineering field; concurrent or recent (past two years) enrollment in group-based project with strong system design component approved by course instructor.

For description, see M&AE 591.

ECE 513(5130) Applied Systems Engineering II (also CEE 505[5050], CS 505[5050], M&AE 592[5920], OR&IE 513[5130], SYSEN 520[5200])

Spring. 3 credits. Prerequisite: CEE 504/CS 504, ECE 512/OR&IE 512, or M&AE 591.

For description, see M&AE 592.

ECE 521(5210) Theory of Linear Systems (also M&AE 521[5210])

Fall. 3 credits. Prerequisite: ECE 320 or permission of instructor. Recommended: good background in linear algebra and linear differential equations.

State-space and multi-input–multi-output linear systems in discrete and continuous time. The state transition matrix, the matrix exponential, and the Cayley-Hamilton theorem. Controllability, observability, stability, realization theory. At the level of Linear Systems by Kailath.

[ECE 522(5220) Nonlinear System Analysis and Computations

Spring. 4 credits. Prerequisite: ECE 521 or a solid background in linear algebra. Real analysis strongly recommended. Next offered 2008–2009.

Rigorous introduction to nonlinear systems. Includes nonlinear differential equations, flows, phase-plane analysis, fundamentals of Lyapunov theory, LaSalle's Theorem, regions of attraction, slowly varying system, advanced stability theory, Lyapunov redesign, applied nonlinear control, describing functions, averaging and singular perturbations, and bifurcation analysis and control and application to physical systems.]

ECE 526(5260) Signal Representation and Modelling

Fall. 4 credits. Prerequisites: ECE 411 and ECE 425.

Sampling and signal reconstruction. Approximation theory. Linear inversion theory. Exponential signal modelling. Multirate filter banks, wavelets, and lifting. Laboratory experiments with speech and image signals.

ECE 531(5310) Applied Quantum Optics for Photonics and Optoelectronics

Spring. 4 credits. Prerequisites: ECE 306 and 407, or PHYS 443.

Introduces the basic concepts of quantum optics and quantum electronics necessary for understanding the behavior of optical fields in photonic and optoelectronic devices and systems. Topics include quantization of the electromagnetic field, quantum mechanical properties of photon states, vacuum fluctuations, noise and quantum Langevin equations, matter-photon interactions, phase-sensitive and phase-insensitive optical amplifiers, direct and coherent photon detection, lasers, parametric oscillators, and photonic devices for quantum information processing.

[ECE 535(5350) Semiconductor Physics

Fall. 4 credits. Prerequisites: ECE 407 and 457, or permission of instructor. Offered alternate years from ECE 537; next offered 2008–2009.

Physics of materials and structures useful in semiconductor electronic and photonic devices, including crystal structure, energy bands, effective mass, phonons, classical low-field transport, high-field and ballistic charge carrier transport, electron scattering by phonons, optical absorption, reflection, optical emissions, deep levels as charge carrier traps, and surface and interface effects.]

ECE 536(5360) Nanofabrication of Semiconductor Devices (also MS&E 541[5410])

Fall. 4 credits. Prerequisites: ECE 315 and ECE 457 or equivalent.

Introduction to modern nanofabrication technologies used to produce integrated circuits. Students perform a series of fabrication steps including lithography, metallization, plasma etching and annealing to realize working semiconductor devices (Schottky diodes, pn junction diodes, MOS capacitors, and MOSFETs) in the lab. Prior knowledge of the operation of these devices is essential as each will be tested to verify the success (or failure) of the fabrication process.

ECE 537(5370) Nanoscale Devices, Circuits, and Physics
Fall, 4 credits. Prerequisites: ECE 457, or permission of instructor. Offered alternate years from ECE 535.
An integrated study connecting semiconductor physics with properties of electronic and optic devices at the nanoscale and the use of electronic devices in circuits. Topics include electronic and optic phenomena in confined structures and in nanoscale limits – single electron phenomena, nanoscale quantum and size effects such as in tunneling and optical transitions , transistor operation in limited scattering limits, plasmonics, molecular transport, interface effects, and the unification of device attributes with implementation in circuits.

ECE 547(5470) Computer Vision
Fall. 4 credits. Prerequisites: ECE 220 (or CS 280 and 314) or permission of instructor.
Covers computer acquisition and analysis of image data with emphasis on techniques for robot vision. Concentrates on descriptions of objects at three levels of abstraction: segmented images (images organized into subimages that are likely to correspond to interesting objects), geometric structures (quantitative models of image and world structures), and relational structures (complex symbolic descriptions of images and world structures). The programming of several computer-vision algorithms is required.

ECE 548(5480) Digital Image Processing
Spring. 4 credits. Prerequisites: ECE 411, ECE 425, and familiarity with linear algebra.
Introduction to image processing through seven major topics: perception, statistical modeling, transforms, enhancement, analysis, compression, and restoration. Special attention is allocated to compression. Equal emphasis is placed on gaining a mathematical and an intuitive understanding of algorithms through actual image manipulation and viewing.

ECE 551(5510) Electric Systems Engineering and Economics (Electricity Markets) (also AEM 655[6550])
Fall. 2 credits. Prerequisites: basic calculus, microeconomics course. Cannot be used as an ECE technical elective.
Designed to explore new arrangements in power system planning and operation brought about by the current restructuring of the electric industry. Organized around lectures on (1) how basic economic principles interact with basic engineering principles used to determine the physical and operational makeup of the system; and (2) the principles and techniques of optimization and their applications to emerging institutional arrangements in the power industry. Involves extensive laboratory work designed to test the principles under discussion. A final requires building an intelligent software agent capable of performing in a competitive market with rules similar to those being set up in the electric power business today. The agents are exercised in a class competition.

ECE 554(5540) Advanced Analog VLSI Circuit Design
Spring. 4 credits. Prerequisite: ECE 453.
Advanced analog integrated circuit and system design. Topics include integrated continuous-time filter design, translinear circuits and systems, dynamic analog techniques, integrated discrete-time filter design, and Nyquist-rate data converter design.

ECE 562(5620) Fundamental Information Theory
Spring. 4 credits. Prerequisite: ECE 411 or equivalent.
Fundamental results of information theory with application to storage, compression, and transmission of data. Entropy and other information measures. Block and variable-length codes. Channel capacity and rate-distortion functions. Coding theorems and converses for classical and multiterminal configurations. Gaussian sources and channels.

ECE 564(5640) Detection and Estimation
Spring. 4 credits. Prerequisites: ECE 310, 411, or permission of instructor.
Graduate-level introduction to fundamentals of signal detection and estimation with applications in communications. Elements of decision theory. Sufficient statistics. Signal detection in discrete and continuous time. Multiuser detection. Parameter estimations. Applications in wireless communications.

ECE 566(5660) Fundamentals of Networks
Fall. 4 credits. Prerequisite: ECE 411. Recommended: ECE 446.
Introductory course on tools and techniques for modeling communication networks, synthesis of network protocols, analysis of network protocols' operation, and performance evaluation of network protocols when deployed in a particular communication network. Analytical tools include advanced probability theory, discrete and continuous-time Markov Chains, queuing theory, and graph theory. Simulation methods and statistical tools for analysis of data obtained from simulation models are studied. The basic mechanisms used in designing communication protocols in wireless and wired networks are illustrated by examples from numerous practical systems. Discussions of some classical papers help students learn about best practices, as well as common mistakes occurring in studies of communication networks.

ECE 567(5670) Digital Communications
Spring 4 credits. Prerequisites: ECE 310, 411, or permission of instructor.
Graduate-level introduction to fundamentals of digital communications. Complex random signals. Digital modulations and optimal receiver principles. Baseband and passband transmissions and processing. Interference channels and equalization techniques. Performance analysis including bit error rate calculation and bounds, cutoff rate and channel capacity. Applications in wireless and digital subscriber loops (DSL).

[ECE 568(5680) Mobile Communication Systems
Spring. 4 credits. Prerequisites: ECE 411 and 467. Next offered 2008–2009.
Theory and analysis of mobile communication systems, with an emphasis on understanding the unique characteristics of these systems. Topics include cellular planning, mobile radio propagation and path loss, characterization of multipath and fading channels, modulation and equalization techniques for mobile radio systems, source coding techniques, multiple access alternatives, CDMA system design, and capacity calculations.]

ECE 572(5720) Parallel Computer Architecture (also CS 516[5722])
Fall. 4 credits. Prerequisite: ECE 475.
Principles and trade-offs in the design of parallel architectures. Emphasis is on latency, bandwidth, and synchronization in parallel machines. Case studies illustrate the history and techniques of shared-memory, message-passing, dataflow, and data-parallel machines. Additional topics include memory consistency models, cache coherence protocols, and interconnection network topologies. Architectural studies presented through lecture and some research papers.

ECE 574(5740) Advanced Digital VLSI
Fall. 4 credits. Prerequisites: ECE 314 and ECE 474.
Top-down approach to asynchronous design and the relation between computer architecture and VLSI design. For the asynchronous design component: high-level synthesis, design by program transformations, and correctness by construction. Topics include delay-insensitive design techniques, description of circuits as concurrent programs, circuit compilation, and electrical optimizations. Students will complete a group project of the design of a microprocessor.

ECE 575(5750) High-Performance Microprocessor Architecture
Spring. 4 credits. Prerequisite: ECE 473 or 475.
Provides in-depth coverage of some of the advanced architectural features of current high-performance microprocessors. Lecture topics include trace caches, branch predictors, value predictors, confidence estimators, finite state machines, multi-threading, predication, software speculation, RISC, EPIC, case studies of modern high-end microprocessors, and research ideas. The projects involve writing simulators to evaluate architectural components on large programs that execute billions of instructions.

ECE 576(5760) Advanced Microcontroller Design
Fall. 4 credits. Prerequisites: ECE 476 and ECE 475 or equivalent.
Design of system-on-chip applications. Students working in pairs design, debug, and construct several systems that illustrate the design of embedded processors with custom peripherals running a real-time operating system. The content focuses on laboratory work. The lectures are used primarily for the introduction of examples, description of specific modules to be designed, and instruction in the hardware and high-level design tools to be employed.

ECE 578(5780) Computer Analysis of Biomed Images
Spring. 4 credits. Prerequisite: instructor permission. Open to students with engineering, biomedical, or biology background.
Powerful imaging modalities with attending computer image processing methods are

evolving for the evaluation of health and the detection of disease. This course focuses on the quantitative analysis of such images and Computer Aided Diagnosis (CAD), i.e., the automatic identification and classification of abnormalities by the computer.

ECE 579(5790) Advanced High-Speed and RF Integrated Circuits

Spring, 4 credits. Prerequisites: ECE 433 and ECE 453.

Principles of analog integrated circuit design in the Giga-Hertz frequency range. This course covers the fundamental understanding of high-frequency circuit building blocks such as low noise amplifiers, mixers, oscillators, phase locked loops, frequency synthesizers, clock and data recoveries, and power amplifiers. Additionally, because some of the traditional microwave building blocks such as transmission lines and distributed circuit elements are essential parts of today's high speed integrated circuits, the course will briefly cover them. Throughout the course, a systematic review of advanced wireless and wireline applications would be covered. The course emphasizes physical understanding and intuitive design methods as well as qualitative techniques and computer simulations. The course has collaborative class projects, based on real-world problems.

ECE 581(5810) Introduction to Plasma Physics (also A&EP 606[6060])

Fall. 4 credits. Prerequisite: ECE 303 or equivalent. First-year graduate-level course; open to exceptional seniors.

Topics include plasma state; motion of charged particles in fields; drift-orbit theory; coulomb scattering, collisions; ambipolar diffusion; elementary transport theory; two-fluid and hydromagnetic equations; plasma oscillations and waves, CMA diagram; hydromagnetic stability; and elementary applications to space physics, plasma technology, and controlled fusion.

ECE 583(5830) Introduction to Technical Management

Fall. 3 credits. Prerequisite: Industrial Experience or equivalent (summer work or school work). For M. Eng. students only.

This course is taught from the perspective of a chief technology officer and is targeted at M. Eng. and management students interested in "real world" problems. It provides an introduction via case examples to the technical, management, and organizational issues of developing and marketing products in high-tech businesses. The focus is on the unique nature of this type of business, including managing with high risk/uncertainty levels, learning to manage very diverse project teams, and recognizing technical versus market success in order to make good business decisions.

[ECE 584(5840) Advanced GPS Receiver Design

Spring. 4 credits. Prerequisite: ECE 415 or M&AE 415. Next offered 2008–2009.

GPS receiver design from the RF section to the observables is investigated and implemented in MATLAB software. Creation of C/A code, upsampling, down conversion, code correlation, acquisition, tracking, and interpreting the navigation message. Students start with the digitized GPS bandwidth and build a software receiver to create the navigation solution as the final project.]

[ECE 585(5850) Upper Atmospheric Physics I

Fall. 4 credits. Prerequisites: physics through 214 or equivalent, introductory chemistry, ECE 486 or equivalent. Next offered 2008–2009.

The structure and dynamics of the ionosphere and upper atmosphere. Charged particle production, loss and transport. Coupling to the neutral atmosphere. Ionospheric instabilities. High-latitude currents and plasma convection and its implications for the ionosphere and upper atmosphere.]

[ECE 586(5860) Upper Atmospheric Physics II

Spring. 4 credits. Prerequisites: ECE 581 and ECE 585. Next offered 2008–2009.

Topics include solar phenomena, solar wind, and space weather; magnetospheric structure and physical processes; plasma instabilities in the ionosphere and magnetosphere; and magnetic reconnection and the relation to high-latitude phenomena.]

ECE 587(5870) Energy Seminar I (also M&AE 545[5450])

Fall. 1 credit.

Energy resources, their conversion to electricity or mechanical work, and the environmental consequences of the energy cycle are discussed by faculty members from several departments in the university and by outside experts. Topics include: energy resources and economics; coal-based electricity generation; nuclear reactors; solar power; energy conservation by users; and air pollution control.

ECE 588(5880) Energy Seminar II (also M&AE 546[5460])

Spring. 1 credit.

For description, see ECE 587; however, different speakers and/or topics are discussed in ECE 588.

[ECE 591(5910) Adaptive Feedback Systems

Fall. 4 credits. Prerequisites: ECE 411, 467, 472, or 521 and MATLAB. Next offered 2008–2009.

Parameter adaptation algorithm construction and tuning for a variety of applications in which an adapted filter is embedded in a feedback loop: telephony echo cancellation, model-following control, recursive identification of pole-zero models, differential pulse code modulation, duct noise control, and decision feedback equalization.]

ECE 593–599(5930–5990) Advanced Topics in Electrical and Computer Engineering

Fall, spring. 1–4 credits.

Seminar, special interest, or temporary course.

[ECE 610(6100) Graduate Seminar in Medical Instrumentation

Fall. 1 credit. S-U grades only. Offered alternate years; next offered 2008–2009.

The seminar will provide a format for identifying, investigating, and discussing state-of-the-art developments related to instrumentation, analysis techniques, and simulation sciences as they apply to biomedical problems and solutions.]

ECE 662(6620) Network Information Theory

Fall. 3 credits. Prerequisite: ECE 562 and permission of instructor.

Second course in information theory, focusing on multiterminal aspects, as covered in the textbooks of Yeung and Csiszar/Koerner.

ECE 683(6830) Seminar in GPS and GNSS

Fall, spring. 1–3 credits. Prerequisite: ECE 415/M&AE 415 or equivalent.

Seminar in GPS (Global Positioning System) and GNSS (Global Navigation Satellite Systems) science and engineering. Current topics in receiver design such as low signal acquisition, ambiguity resolution, and software receivers and topics in GPS science such as space weather effects on GPS and the use of GPS for remote sensing. Students typically make one presentation during the semester.

ECE 685(6850) Memory Technologies and Systems

Fall. 4 credits. Prerequisites: ECE 314, ECE 475, or permission of instructor. Cannot be used as an ECE technical elective.

Covers various aspects of the Memory Wall Problem. Students study memory systems from the lowest building blocks on up. The course begins with a review of Virtual Memory to prepare for studying "adaptable" or "active" memory controllers that use their own TLBs and page tables to remap addresses. Modern DRAM designs, memory access ordering and scheduling, and seminal memory system papers from the literature will be covered. Other topics include PIM and interesting new memory technologies for uses other than main memory.

ECE 693(6930) Master of Engineering Design

Fall, spring. 3–8 credits. Must enroll both semesters; will receive R grade for first semester. For students enrolled in M.Eng. (Electrical) degree program.

Uses real engineering situations to present fundamentals of engineering design. Each professor is assigned a section number. To register, see roster for appropriate six-digit course ID numbers.

ECE 697–698(6970–6980) Master of Engineering Research

697, fall; 698, spring. 7 credits. Prerequisite: For students enrolled in M.Eng. (Electrical) degree Research Track program. Must enroll both semesters.

Project designed for the M.Eng. student in the Research Track program and more resembles a research thesis. Students will work closely with an ECE Graduate Field Faculty member on a common area of interest. Each professor is assigned a section number. To register, see roster for appropriate six-digit course ID numbers.

ECE 791–792(7910–7920) Thesis Research

791, fall; 792, spring. 1–15 credits. For students enrolled in master's or doctoral program. Each professor is assigned a section number. To register, see roster for appropriate six-digit course ID numbers.

INFORMATION SCIENCE, SYSTEMS, AND TECHNOLOGY

C. Cardie, director; W. Arms, G. Bailey, K. Bala, R. Caruana, E. Friedman, J. Gehrke, C. Gomes, J. Halpern, D. Huttenlocher, P. Jackson, T. Joachims, J. Kleinberg, L. Lee, D. Ruppert, P. Rusmevichientong, B. Selman, D. Shmoys, E. Tardos, D. Williamson

For complete descriptions, see the INFO listing in the CIS section.

INFO 130(1300) Introductory Design and Programming for the Web (also CS 130[1300])
Fall. 3 credits.
For description, see INFO 130 in CIS section.

[INFO 172(1700) Computation, Information, and Intelligence (also COGST 172, CS 172[1700], ENGRI 172[1700])
Fall or spring. 3 credits. Prerequisite: some knowledge of differentiation; freshman standing or permission of instructor. Next offered 2008–2009.
For description, see CS 172 in CIS section.]

INFO 204(2040) Networks (also ECON 204[2040], SOC 209[2120]) (SBA)
Spring. 4 credits.
For description, see ECON 204.

INFO 214(2140) Cognitive Psychology (also COGST 214, PSYCH 214[2140]) (KCM)
Fall. 4 credits. Limited to 175 students. Prerequisite: sophomore standing. Graduate students, see INFO/PSYCH 614.
For description, see PSYCH 214.

INFO 230(2300) Intermediate Design and Programming for the Web (also CS 230[2300])
Spring. 3 credits. Prerequisite: CS/INFO 130 or equivalent.
For description, see INFO 230 in CIS section.

INFO 245(2450) Psychology of Social Computing (also COMM 245[2450]) (SBA)
Fall. 3 credits.
For description, see COMM 245.

[INFO 292(2921) Inventing an Information Society (also AM ST 292[2980], ECE/ENGRG 298[2980], HIST 292[2920], S&TS 292[2921])
Spring. 3 credits. May not be taken for credit after ECE/ENGRG 198. Next offered 2008–2009.
For description, see ENGRG 298.]

INFO 295(2950) Mathematical Methods for Information Science
Fall. 4 credits. Corequisite: MATH 231 or equivalent.
For description, see INFO 295 in CIS section.

INFO 320(3200) New Media and Society (also COMM 320[3200])
Spring. 3 credits.
For description, see COMM 320.

INFO 330(3300) Data-Driven Web Applications (also CS 330[3300])
Fall. 3 credits. Prerequisite: CS/ENGRD 211.
For description, see INFO 330 in CIS section.

INFO 345(3450) Human-Computer Interaction Design (also COMM 345[3450]) (SBA)
Spring. 3 credits.
For description, see COMM 345.

INFO 349(3491) Media Technologies (also COMM 349[3490], S&TS 349[3491]) (CA)
Spring. 3 credits.
For description, see COMM 349.

INFO 355(3551) Computers: From the 17th Century to the Dot.com Boom (also S&TS 355[3551]) (HA)
Fall. 4 credits.
For description, see S&TS 355.

[INFO 356(3561) Computing Cultures (also S&TS 356[3561])]

INFO 366(3650) History and Theory of Digital Art (also ART H 366[3650]) (CA)
Fall. 4 credits.
For description, see ART H 366.

INFO 372(3720) Explorations in Artificial Intelligence (also CS 372[3700])
Spring. 3 credits. Prerequisites: MATH 111 or equivalent, an information science approved statistics course, and CS 211 or permission of instructor.
For description, see INFO 372 in CIS section.

[INFO 387(3871) The Automatic Lifestyle: Consumer Culture and Technology (also S&TS 387[3871]) (CA)
Spring. 4 credits. Next offered 2008–2009.
For description, see S&TS 387.]

INFO 415(4150) Environmental Interventions (also S HUM 415)
Fall. 4 credits.
For description, see S HUM 415.

INFO 429(4290) Copyright in the Digital Age (also COMM 429[4290])
Fall. 3 credits.
For description, see COMM 429.

INFO 430(4300) Information Retrieval (also CS 430[4300])
Fall. 3 credits. Prerequisite: CS/ENGRD 211 or equivalent.
For description, see INFO 430 in CIS section.

INFO 431(4302) Web Information Systems (also CS 431[4302])
Spring. 3 credits. Prerequisites: CS 211 and some familiarity with web site technology.
For description, see INFO 431 in CIS section.

INFO 435(4350) Seminar on Applications of Information Science (also INFO 635[6390])
Spring. 3 credits. Prerequisites: background in computing, data structures, and programming at level of CS 211 or equivalent; experience using information systems. Undergraduate and master's students should register for INFO 435; Ph.D. students should register for INFO 635.
For description, see INFO 435 in CIS section.

INFO 440(4400) Advanced Human-Computer Interaction Design (also COMM 440[4400]) (SBA)
Fall. 3 credits. Prerequisite: COMM/INFO 245.
For description, see COMM 440.

INFO 444(4144) Responsive Environments (also ART H 444[4144]) (CA)
Spring. 4 credits.
For description, see ART H 444.

[INFO 445(4450) Seminar in Computer-Mediated Communication (also COMM 445[4450])
Fall. 3 credits. Prerequisite: COMM/INFO 245. Next offered 2009–2010.
For description, see COMM 445.]

INFO 447(4470) Social and Economic Data (also ILRLE 447[4470])
Spring. 4 credits. Prerequisites: one semester of calculus, IS statistics requirement, one upper-level social science course, or permission of instructor.
For description, see INFO 447 in CIS section.

INFO 450(4500) Language and Technology (also COMM 450[4500]) (SBA)
Spring. 3 credits. Prerequisite: COMM 240 or COMM 245 or permission of instructor.
For description, see COMM 450.

INFO 490(4900) Independent Reading and Research
Fall, spring. 1–4 credits.

INFO 491(4910) Teaching in Information Science, Systems, and Technology
Fall, spring. Variable credit.

INFO 515(5150) Culture, Law, and Politics of the Internet
Fall. 4 credits.
For description, see INFO 515 in CIS section.

INFO 530(5300) The Architecture of Large-Scale Information Systems (also CS 530[5300])
Spring. 4 credits. Prerequisite: CS/INFO 330 or CS 432.
For description, see INFO 530 in CIS section.

INFO 614(6140) Cognitive Psychology (also COGST 614[6140], PSYCH 614[6140])
Fall. 4 credits.
For description, see PSYCH 614.

INFO 630(6300) Advanced Language Technologies (also CS 674[6740])
Fall or spring; in 2007–2008, offered in fall. 3 credits. Prerequisite: permission of instructor. Neither INFO/CS 430 nor CS 474 are prerequisites.
For description, see CS 674 in CIS section.

INFO 635(6390) Seminar on Applications of Information Science (also INFO 435[4350])
Spring. 3 credits. Prerequisites: background in computing, data structures, and programming at level of CS 211 or equivalent; experience in using information systems. Undergraduates and master's students should register for INFO 435; Ph.D. students should register for INFO 635.
For description, see INFO 635 in CIS section.

INFO 640(6400) Human-Computer Interaction Design (also COMM 640[6400])
Fall. 3 credits. Prerequisite: graduate standing or permission of instructor.
For description, see COMM 640.

INFO 645(6450) Seminar in Computer-Mediated Communication (also COMM 645[6450])
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor.
For description, see COMM 645.

INFO 648(6648) Speech Synthesis by Rule (also LING 648[6648])
Spring. 4 credits. Prerequisite: LING 401, 419, or permission of instructor.
For description, see LING 648.

INFO 650(6500) Language and Technology (also COMM 650[6500])
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor.
For description, see COMM 650.

[INFO 651(7002) Critical Technical Practices]

INFO 685(6850) The Structure of Information Networks (also CS 685[6850])
Fall. 4 credits. Prerequisite: CS 482.
For description, see INFO 685 in CIS section.

INFO 709(7090) IS Colloquium
Fall, spring. 1 credit. For staff, visitors, and graduate students interested in information science.

INFO 747(7400) Social and Economic Data (GR-RDC) (also ILRLE 740[7400])
Spring. 4 credits. Prerequisite: Ph.D. and research master's students.
For description, see INFO 747 in CIS section.

INFO 790(7900) Independent Research
Fall, spring. Variable credit. Prerequisite: permission of an information science faculty member.
Independent research for M.Eng. students and pre–A exam Ph.D. students.

INFO 990(9900) Thesis Research
Fall, spring. Variable credit. Prerequisite: permission of an information science faculty member.
Thesis research for post–A exam Ph.D. students.

MATERIALS SCIENCE AND ENGINEERING

E. P. Giannèlis, director; D. G. Ast, S. P. Baker, J. M. Blakely, R. Dieckmann, L. Estroff, D. T. Grubb, R. Hennig, C. Liddell, G. G. Malliaras, C. K. Ober, S. L. Sass, M. O. Thompson, C. C. Umbach, R. B. van Dover, U. B. Wiesner

Undergraduate Courses

MS&E 111(1110) Nanotechnology (also ENGRI 111[1110])
Fall. 3 credits. E. Giannelis.
Course in Introduction to Engineering series.
For description, see ENGRI 111.

MS&E 118(1180) Design Integration: DVDs and iPods (also ENGRI 118[1180], T&AM 118[1180])
Spring. 3 credits. Course in Introduction to Engineering series.
For description see ENGRI 118.

MS&E 119(1190) Biomaterials for the Skeletal Systems (also ENGRI 119[1190])
Fall. 3 credits. D. Grubb.
Course in Introduction to Engineering series.
For description, see ENGRI 119.

MS&E 206(2060) Atomic and Molecular Structure of Matter (also M&AE 313[3130])
Spring. 4 credits. C. Liddell.
Discusses the basic elements of structure; order and disorder; ideal gas; crystals; liquids; amorphous materials; polymers; liquid crystals; composites; crystal structure; x-ray diffraction.

MS&E 261(2610) Mechanical Properties of Materials: From Nanodevices to Superstructures (also ENGRD 261[2610])
Fall. 3 credits. S. L. Sass.
For description, see ENGRD 261.

MS&E 262(2620) Electronic Materials for the Information Age (also ENGRD 262[2620])
Spring. 3 credits. Prerequisite: MATH 192. Corequisite: PHYS 213 or permission of instructor. G. Malliaras.
For description, see ENGRD 262.

MS&E 269(2690) Technologies for Making the Small
Spring. 3 credits. Prerequisites: CHEM 207/211, MATH 192. M. Thompson.
This course provides an introduction to principles and practice of nanofabrication techniques, combining lectures with hands-on laboratory fabrication. A range of nanosystems is explored from microelectronic circuits to MEMS sensors and/or microfluids. Fundamentals common to all fabrication including lithography, deposition, and etching processes are explored in lectures and lab exercises. New developments in "soft" microstamp lithography and self-assembly methods are discussed. In the final project students build one of several nanosystems depending on their interests.

MS&E 291–292(2910–2920) Research Involvement IIa and IIb
291, fall; 292, spring. 3 credits each semester. Prerequisite: approval of department. Staff.
Supervised independent research project in association with faculty members and faculty research groups of the department. Students design experiments, set up the necessary equipment, and evaluate the results. Creativity and synthesis are emphasized. Each semester may be taken as a continuation of a previous project or as a one-semester affiliation with a research group.

MS&E 301(3010) Materials Chemistry (also MS&E 581[5810])
Fall. 3 credits. L. Estroff.
Provides a molecular understanding of materials properties: quantum chemistry, symmetry aspects of chemical bonding, solid state reactions, and electrochemistry. Materials include polymers, organic semiconductors, organic-inorganic hybrids, and biomaterials.

MS&E 303(3030) Thermodynamics of Condensed Systems (also MS&E 583[5830])
Fall. 4 credits. Prerequisites: PHYS 214 and MATH 294. M. O. Thompson.
Introduces the three laws of thermodynamics as the fundamental basis for thermal and chemical equilibrium, coupled with statistical mechanical interpretations for entropy and specific heat capacities. Applies these principles to understanding phase equilibria and phase diagrams, heterogeneous reactions, solutions, surfaces, and defects. Introduces electrochemistry and fuel/power cells.

MS&E 304(3040) Kinetics, Diffusion, and Phase Transformations (also MS&E 584[5840])
Spring. 4 credits. Prerequisite: MS&E 303 or permission of instructor. R. Hennig.
Topics include phenomenological and atomistic theories of diffusion; diffusion in metals, alloys, and nonmetals, including polymers; diffusion in the presence of driving forces; fast diffusion paths; thermo- and electrotransport; interfaces and microstructure; nucleation and growth; growth of product layers (parabolic and linear kinetics); solidification of alloys; diffusional and diffusionless transformations in solids; glass transition.

MS&E 305(3050) Electronic, Magnetic, and Dielectric Properties of Materials (also MS&E 585[5850])
Spring. 3 credits. Prerequisite: MS&E 206 or permission of instructor. R. B. van Dover.
Electronic structure of materials and connection to transport, magnetic, and dielectric properties. Wave and particle nature of electrons, wave packets, potential wells, barriers, tunneling. Valence electron behavior in crystals, density of states for metals, Fermi level, field and thermionic emission, Schottky barriers. Periodic potentials and band structure of crystals. Intrinsic and doped semiconductors, junction electronic and optical devices. Physical origin of magnetic behavior, ferromagnetic domains, magnetoresistance. Materials for data storage and manipulation. Polarization in dielectric materials; frequency dependence of dielectric constants and refractive indices. Ferroelectric domains. Dielectric components in devices. The close connection between fundamental concepts and current technology is emphasized.

MS&E 307(3070) Materials Design Concepts I
Fall. 2 credits. J. Blakely.
For description, see MS&E 407.

MS&E 311(3110) Junior Laboratory I
Fall. 1 credit. D. Ast.
Practical laboratory covering the analysis and characterization of materials and processing. Labs are based on materials from courses in thermodynamics of condensed systems and electronic, magnetic, and dielectric properties of materials.

MS&E 312(3120) Junior Laboratory II
Spring. 1 credit. D. Ast.
Practical laboratory covering the analysis and characterization of materials and processing. Labs are based on course material in kinetics, diffusion, and phase transformation and mechanical properties of materials, processing, and design.

MS&E 391–392(3910–3920) Research Involvement IIIa and IIIb
391, fall; 392, spring. 3 credits each semester. Prerequisite: departmental approval. Staff.
For description, see MS&E 291. May be continuation or a one-semester affiliation with a research group.

MS&E 402(4020) Mechanical Properties of Materials, Processing, and Design (also M&AE 312[3120], MS&E 582[5820])
Fall. 3 credits. Prerequisite: MS&E 206. Corequisite: MS&E 304 or permission of instructor. S. Baker.

Relationship between microscopic mechanisms and macroscopic mechanical behavior of engineering materials, how mechanical properties can be modified, and criteria for selection and use of materials in design. Stress, strain and elastic constants as tensor quantities, viscoelasticity and damping, plastic deformation, creep deformation, fracture, and fatigue.

MS&E 403–404(4030–4040) Senior Materials Laboratory I and II

403, fall,; 404, spring, 3 credits each semester. Staff.

Practical laboratory covering the analysis and characterization of materials and processing. Emphasis is on design of experiments for evaluation of materials' properties and performance as related to processing history and microstructure. Projects available in areas such as plasticity, mechanical and chemical processing, phase transformations, electrical properties, magnetic properties, and electron microscopy.

MS&E 405–406(4050–4060) Senior Thesis I and II

405, fall; 406 spring. 4 credits each semester. Requirement for graduation with honors. Open to advanced undergraduates in lieu of senior materials laboratory. M. Thompson.

Proposals for thesis topics should be approved by the supervising faculty member before beginning the senior year. Approved thesis topics normally involve original experimental research in direct collaboration with an ongoing research program. Periodic oral and written presentations and a final written thesis are required. Students must take both semesters to complete the laboratory requirement.

MS&E 407(4070) Materials Design Concepts II

Fall. 2 credits. J. Blakely.

Introduces materials design in the context of real world materials design projects carried out in industry. In the first portion of the course, the process of engineering design is studied in light of economic, environmental, regulatory, and safety issues. Patent searching and communication skills are addressed. In the second portion, speakers from industry lecture on case studies of materials design problems. Students give oral presentations and write technical reports based on case studies.

MS&E 410(4100) Physical Metallurgy and Applications (also MS&E 610[6100])

Spring. 3 credits. Prerequisites: MS&E 206, 303, 304 or permission of instructor. S. Baker.

Microstructure and properties of metals and alloys: processing, structure, defects, phase stability, diffusion, deformation, fracture, corrosion, conductivity, optical properties. Applications of metallurgical principles to high performance metallic materials include: thin films and patterned structures for use in microelectromechanical systems, superalloys for high temperature engine applications, shape memory alloys for biomedical applications, and others.

MS&E 433(4330) Materials for Energy Production, Storage, and Conversion (also MS&E 533[5330])

Fall. 3 credits. R. Dieckmann.

Concerned with materials and technologies related to energy production, storage, and conversion as well as to sensors used for monitoring the emission of pollutants. The devices discussed include solar cells, fuel cells, batteries, and electrochemical sensors. Thermodynamic, kinetic, and electrochemical concepts and materials properties critical for such devices are the central part of this course.

MS&E 461(4610) Biomedical Materials and Their Applications

Spring. 3 credits. L. Estroff.

Many types of materials are used in biomedical engineering to replace or supplement natural biological systems. Interaction with blood and tissues is always of primary importance, but depending on the use of the biomedical material, mechanical, optical, and transport properties may also be vital. After a general introduction to biomedical materials, case studies involving physiological systems are considered, and design of artificial parts and materials are investigated. Constraints such as methods of production, economics, regulatory approval, and legal liabilities are included. Examples may include dialysis, contact and intra-ocular lenses, heart valves, and the artificial pancreas. Every student is involved in a presentation about a case study.

[MS&E 481(4810) Technology Management (also MS&E 587[5870])

Spring. 3 credits. Next offered 2008–2009. E. P. Giannelis.

Designed to provide students in engineering and the sciences with the knowledge and analytical skills to manage RD for a strategic competitive advantage. Most organizations recognize the critical importance of RD management in becoming and remaining world-class competitors. The course uses a combination of case studies, readings, discussions, and outside lectures. Topics include technology evaluation, RD portfolio, intellectual property portfolio and management, technology transfer, and technology, policy, and society.]

MS&E 482(4820) Plasma Processing of Electronic Materials (also ECE 482[4820])

Spring. 3 credits. Prerequisites: PHYS 213 and 214 or equivalents. Offered if sufficient demand.

For description, see ECE 482.

[MS&E 487(4870) Ethics and Technology

Spring. 1 credit. Next offered 2008–2009. Staff.

Ethics influences all decisions made by a technologist. This course discusses those factors that must be considered in reaching a decision involving technology, ranging from legal impact to consideration of community expectations.]

[MS&E 489(4890) Colloids and Colloid Assemblies for Advanced Materials Applications (also MS&E 589[5890])

Fall. 3 credits. C. Liddell. Next offered 2008–2009.

Recent global developments in the synthesis, modification, organization, and utilization of fine particles in nanotechnology and biotechnology fields. Underlying principles for control of particle characteristics such as mean size, shape, composition, internal homogeneous structure, layered, hollow, porous, and heterojunction structures. Methods for the formation of ordered and patterned particle arrays employed in advanced materials based on latex, ceramic colloids, metal nanoparticles, semiconductor quantum dots, nanocapsules, and miniemulsions. Applications in photonics, biolabeling, biological screening, drug delivery, catalysis, and magnetic recording.]

MS&E 491–492(4910–4920) Research Involvement IVa and IVb

491, fall; 492, spring. 3 credits each semester. Prerequisite: departmental approval. Staff.

For description, see MS&E 291. May be continuation or a one-semester affiliation with a research group.

MS&E 495(4950) Undergraduate Teaching Involvement

Fall, spring. Variable credit. Staff.

Gives credit to students who help in the laboratory portions of select MS&E courses. The number of credits earned is determined by the teaching load and is typically 1–3.

MS&E 501–502(5010–5020) Special Project

Fall, spring. 6 credits. Staff.

Master of Engineering research project.

[MS&E 512(5120) Mechanical Properties of Thin Films (also M&AE 513[5130])

Spring. 3 credits. Next offered 2008–2009. S. P. Baker.

Stresses, elastic and plastic deformation, creep and anelasticity, and fracture and delamination of thin films and patterned structures. How mechanical behavior at the nanoscale deviates from the predictions of scaling laws derived for bulk materials. Applications in microelectronics, optics, microelectromechanical systems, coatings, etc.]

MS&E 521(5210) Properties of Solid Polymers

Fall. 3 credits. Prerequisite: ENGRD 261. Corequisite: MS&E 303 or permission of instructor. C. Ober.

Synthetic and natural polymers for engineering applications. Production and characterization of long-chain molecules. Thermodynamics of polymer mixtures. Polymer molecular weight. Gelation and networks, rubber elasticity, elastomers, and thermosetting resins. Amorphous and crystalline thermoplastics and their structure. Time- and temperature-dependent elastic properties of polymers. Glass transition and secondary relaxations. Plastic deformation and molecular orientation.

MS&E 523(5230) Physics of Soft Materials

Fall. 3 credits. U. Wiesner.

The course covers general aspects of structure, order, and dynamics of soft materials. Typical representatives of this class of materials are polymers, liquid crystals, gels, and surfactant solutions. A general formalism for the description of order in terms of orientation distribution functions is introduced. Examples are given for the measurement of order parameters for partially ordered materials. Finally, the dynamics of soft materials is discussed. Besides transport and flow behavior aspects of the local dynamics of soft materials are presented. Emphasis is put on the discussion of various techniques frequently used (and available at Cornell) for the characterization of structure, order and dynamics of soft materials such as NMR or various scattering techniques. Using examples of modern multidimensional spectroscopic methods the issue of heterogeneous dynamics at the glass transition of amorphous liquids is presented at the end of the class.

[MS&E 525(5250) Organic Optoelectronics

Fall. 3 credits. Next offered 2008–2009. G. G. Malliaras.

The course begins with an overview of relevant materials, from small aromatic molecules to conjugated polymers. We then discuss their optoelectronic properties, including topics from photophysics (absorption, emission, photogeneration, recombination), charge transport and injection (doping, hopping, disorder) and nonlinear optics. Molecular conduction mechanisms are reviewed. Their applications in electrophotography, light emitting diodes, lasers, photovoltaic cells, thin film transistors are then discussed.]

[MS&E 531(5310) Introduction to Ceramics

Spring. 3 credits. R. Dieckmann. Next offered 2008–2009.

Covers ceramic processes and products, structure of ceramic crystals, structure of glasses, structural defects (point defects, dislocations), surfaces, interfaces and grain boundaries, diffusion in ionic materials (atomistic and phenomenological approach, relationships between diffusion and point defect structure), ceramic phase diagrams, phase transformations. Emphasizes physicochemical aspects of the different topics.]

MS&E 533(5330) Materials for Energy Production, Storage, and Conversion (also MS&E 433[5330])

Fall. 3 credits. R. Dieckmann.

For description, see MS&E 433.

MS&E 541(5410) Nanofabrication of Semiconductor Devices (also ECE 536[5360])

Fall. 4 credits. Prerequisites: ECE 315 and ECE 457 or equivalent.

For description, see ECE 536.

[MS&E 542(5420) Flexible Electronics

Spring. 3 credits. Next offered 2008–2009. C. Ober.

Flexible electronics holds the promise of transformative developments in: (1) flat panel lighting (low cost, low energy), (2) energy production systems (solar), and (3) infrastructure control and monitoring (sensing, energy control, hazard monitoring). Practical realization of flexible circuits will require dramatic progress in new materials that are compatible with flexible media and amenable to facile and low temperature processing as well as major advances in manufacturing technologies such as roll-to-roll processing. This course will discuss these and other developments.]

MS&E 543(5430) Thin-Film Materials Science

Fall. 3 credits. R. B. van Dover.

Provides fundamental information on the deposition, properties, reaction, and evaluation of thin films. Topics include deposition techniques, surface energies, stress in thin films, surface kinetics, homoepitaxy, heteroepitaxy and superlattices, electrical and optical properties, Schottky barriers, solid phase regrowth, interdiffusion, thin film reactions, and electromigration. The recommended textbook is *Electronic Thin Film Science for Electrical Engineers and Material Scientists* by Tu, Mayer, and Feldman.

[MS&E 545(5450) Magnetic and Ferroelectric Materials

Fall. 3 credits. Prerequisites: PHYS 213 and 214 or equivalent. Next offered 2008–2009. R. B. van Dover.]

MS&E 555(5550) Introduction to Composite Materials (also CEE/M&AE/T&AM 455[4550])

Spring. 3 credits.

For description, see T&AM 455.

[MS&E 562(5620) Biomineralization: The Formation and Properties of Inorganic Biomaterials

Spring 3 credits. Prerequisites: MS&E 301 or CHEM 257 or CHEM 357–358 or equivalent or permission of instructor. Next offered 2008–2009.

This course will examine the wide variety of mineralized materials made by biological organisms including mollusk shells, mammalian bone and teeth, silica bodies in plants, and magnetotactic bacteria. The focus will be on the molecular and biological mechanisms that lead to the formation of these materials as well as their unique materials properties (mechanical, optical, magnetic).]

MS&E 563(5630) Nanobiotechnology (also A&EP/BIO G 663[6630])

Spring. 3 credits.

For description, see A&EP 663.

MS&E 571(5710) Analytical Techniques for Material Science

Spring. 3 credits. D. Grubb.

Survey of modern analytical techniques used to determine composition and structure of near-surface and bulk materials. Interaction of ions, electrons, and photons with solids; characteristics of the emergent radiation. Techniques covered include ion scattering, Auger electron spectroscopy, nuclear activation, secondary ion mass spectroscopy, UV and X-ray photoelectron spectroscopies, and X-ray techniques. Selection and design of experiments.

MS&E 572(5720) Computational Materials Science

Fall. 3 credits. Prerequisite: MS&E 303/601 or equivalent. R. Hennig.

Computational methods for predicting the behavior of condensed matter systems, including Monte Carlo, molecular dynamics, and phase field approaches. Extraction of physical parameters from simulation results and limitations of computational methods. Survey of interatomic potential development and quantum-mechanical ab-initio techniques. Examples drawn from surface and condensed phase systems.

MS&E 581(5810) Materials Chemistry (also MS&E 301[3010], M&AE 312[3120])

Spring. 3 credits. L. Estroff.

For description, see MS&E 301.

MS&E 582(5820) Mechanical Properties of Materials, Processing, and Design (also MS&E 402[4020], M&AE 312[3120])

Fall. 3 credits. Corequisite: MS&E 584 or permission of instructor. S. Baker.

For description, see MS&E 302.

MS&E 583[5830] Thermodynamics of Condensed Systems (also MS&E 303[3030])

Fall. 4 credits. M. O. Thompson.

For description, see MS&E 303.

MS&E 584(5840) Kinetics, Diffusion, and Phase Transformation (also MS&E 304[3040])

Spring. 4 credits. Prerequisite: MS&E 583 or permission of instructor. R. Hennig.

For description, see MS&E 304.

MS&E 585(5850) Electronic, Magnetic, and Dielectric Properties of Materials (also MS&E 305[3050])

Spring. 3 credits. R. B. van Dover.

For description, see MS&E 305.

[MS&E 587(5870) Technology Management (also MS&E 481[4810])

Spring. 3 credits. Next offered 2008–2009. E. P. Giannelis.

For description, see MS&E 481.]

[MS&E 589(5890) Colloids and Colloid Assemblies for Advanced Materials Applications (also MS&E 489[4890])

Fall. 3 credits. Next offered 2008–2009. C. Liddell.

For description, see MS&E 489.]

Graduate Core Courses

MS&E 601(6010) Chemistry of Materials

Spring. 3 credits. Prerequisite: thermodynamics course at level of MS&E 303. C. Ober.

Topics include basic statistical thermodynamics, partition functions and thermodynamic state functions, distributions, laws of thermodynamics, free-energy functions and conditions of equilibrium, chemical reactions, statistics of electrons in crystals, heat capacity, heterogeneous systems and phase transitions, and lattice models of 1-, 2-, and 3-dimensional interacting systems. Also covers: statistical thermodynamics of alloys, free-energy and phase diagrams, order-disorder phenomena, point defects in crystals, and statistical thermodynamics of interfaces.

[MS&E 602(6020) Elasticity, Plasticity, and Fracture

Spring. 3 credits. Next offered 2008–2009.]

[MS&E 603(6030) Thermodynamics of Materials

Spring. 3 credits. Next offered 2008–2009. J. Blakely.]

MS&E 604(6040) Kinetics of Reactions in Condensed Matter

Spring. 3 credits. R. Dieckmann.

Phenomenology and microscopic aspects of diffusion in fluids, both simple and polymeric, and in metallic, ionic, semiconductor, and polymeric solids. Cartesian tensors are utilized for fields and properties. Covers phase stability and transformations; nucleation and growth, spinodal decomposition and displacive transformations; phase coursening processes, recrystallization, and grain growth; diffusion-controlled growth, interfacial reactions, moving boundary problems; grain-boundary migration controlled kinetics; viscosity, anelasticity, and diffusional creep.

[MS&E 605(6050) Electronic Properties of Materials

Fall. 4 credits. Next offered 2008–2009. R. B. Van Dover.

Methods to characterize structure of materials. Elements of Structure at length scales ranging from sub-nanometer to millimeter. Crystals, Liquids, Amorphous Solids/Glasses Short and long-range structures. Techniques to Probe Structure. Real space imaging, including probe microscopies, optical, electron and X-ray methods. Diffraction methods. Applications of structural methods may include, Polymers, Polycrystalline Metals, Dislocation, Biological Membranes, Nano-Composite, Surfaces, Interfaces in Semiconductors, Photonic Materials, Domains in Ferroelectrics and Ferromagnetics, Biological materials.]

[MS&E 606(6060) Condensed Matter Structure

Spring. 3 credits. Prerequisite: course at level of MS&E 206. Next offered 2008–2009. J. Blakely.

Focuses on ways to characterize structure. Includes lectures by several faculty on structural determination on a wide range of materials. Elements of structure at length scales ranging from sub-nanometer to millimeter. Descriptions of structure in crystals, liquids, amorphous solids/glasses. Short- and long-range order, microstructures, cellular structures, domains, domain boundaries, 2-phase and composite structures. Techniques to probe structure: "direct" microscopy, real space imaging, including probe microscopies, optical, electron and X-ray methods. Indirect methods based on analysis of diffraction fields, Fourier/reciprocal space. Examples of application may include polymer structure, metal grain textures, dislocation arrays, cellular structure, structure of biological membranes, nano-composite structures, surfaces, interfaces and grain boundaries in semiconductors, structure of photonic materials, domain structures in ferroelectrics and ferromagnetics, biological materials.]

Related Course in Another Department

Introductory Solid-State Physics (PHYS 454, A&EP 450)

Further Graduate Courses

[MS&E 610(6100) Physical Metallurgy and Applications (also MS&E 410[4100])

Spring. 3 credits. Prerequisites: MS&E 206, 303, 304 or permission of instructor. Next offered 2008–2009. S. Baker.

For description, see MS&E 410.]

MS&E 621(6210) Advanced Inorganic Chemistry III: Solid-State Chemistry (also CHEM 607[6070])

Fall. 4 credits. Prerequisite: CHEM 605 or permission of instructor. S. Lee.

For description, see CHEM 607.

MS&E 655(6550) Composite Materials (also M&AE/T&AM 655[6550])

Spring. 4 credits. Staff.

For description, see T&AM 655.

MS&E 665(6650) Principles of Tissue Engineering (also M&AE/BME 665[6650])

Spring. 3 credits. Prerequisite: graduate standing or permission of instructor.

For description, see BME 665.

MS&E 671(6710) Principles of Diffraction (also A&EP 711[7110])

Fall. 3 credits. Letter grades only. Assumes some knowledge of statistical thermodynamics, crystallography, elementary quantum mechanics, and theory of rate processes. J. D. Brock.

For description, see A&EP 711.

[MS&E 681(6810) Surfaces and Interfaces in Materials

Spring. 3 credits. Next offered 2008–2009. J. Blakely.

Deals with special topics in surface and interface science. The main topics are: statistical thermodynamics of interfaces, morphological stability, atomic structure, energetics and structure determination, electronic structure of interfaces, charge and potential distributions, surface steps, adsorption and segregation, atomic transport and growth processes at surfaces, oxidation, and other surface reactions.]

Specialty Courses

MS&E 800(8000) Research in Materials Science

Fall, spring. Credit TBA. Staff.

Independent research in materials science under the guidance of a member of the staff.

MS&E 801(8010) Materials Science and Engineering Colloquium

Fall and spring. 1 credit each semester. Enrollment limited to MS&E Ph.D. students. Staff.

Lectures by visiting scientists, Cornell staff members, and graduate students on subjects of interest in materials sciences, especially in connection with new research.

MS&E 802(8020) Materials Science Research Seminars

Fall, spring. 2 credits each semester. Prerequisite: graduate students involved in research projects. Staff.

Short presentations on research in progress by students and staff.

MECHANICAL AND AEROSPACE ENGINEERING

P. L. Auer, C. T. Avedisian, D. L. Bartel, L. J. Bonassar, J. F. Booker, J. R. Callister, M. E. Campbell, D. A. Caughey, L. R. Collins, P. R. Dawson, P. C. T. deBoer, D. C. Erickson, E. M. Fisher, E. Garcia, A. R. George, F. C. Gouldin, C. Hui, B. J. Kirby, S. Leibovich, H. Lipson, M. Y. Louge, J. L. Lumley, M. P. Miller, F. C. Moon, F. K. Moore, S. Mukherjee, M. A. Peck, R. M. Phelan, S. L. Phoenix, S. B. Pope, M. L. Psiaki, E. L. Resler, Jr., A. Ruina, W. Sachse, K. E. Torrance, M. C. H. van der Meulen, H. B. Voelcker, K. K. Wang, Z. Warhaft, C. H. K. Williamson, N. Zabaras, A. Zehnder, K. M. Zhang

M&AE 103(1030) Introduction to Computer-Aided Manufacture (CAM)

Fall, spring, approx. eight weeks (total 15 hrs. of instruction and 15 hrs. of lab). 1 credit, Limited enrollment. Prerequisites: M&AE 225 or equivalent experience and completion of Emerson Lab Product Realization Facility's CNC seminars: An Introduction to CNC Machining and CNC Programming; or permission of instructor.

Completes the introduction to the fundamentals of computer-aided manufacture (CAM) seminars through the use of computer numerical control (CNC) programming. The course is the hands-on component of the three-part series on CAM. Provides practical applications of the use of G codes and solid modeling software, CNC mill and/or lathe setup, tool selection, and operation. The course is required for students wishing to use the CNC equipment in the Emerson Lab's Product Realization Facility for team or research projects. May not be used to fulfill any M&AE requirement.

M&AE 111(1110) Naval Ship Systems (also NAV S 202[2020])

Fall. 3 credits.

For description, see NAV S 202.

M&AE 117(1170) Introduction to Mechanical Engineering (also ENGRI 117[1170])

Fall. 3 credits. 2 lec and 1 lab per week.

Course in Introduction to Engineering series. For description, see ENGRI 117.

M&AE 127(1270) Introduction to Entrepreneurship and Enterprise Engineering (also ENGRI 127[1270])

Spring. 3 credits. Open to all Cornell students regardless of major. Prerequisites: none.

For description, see ENGRI 127.

M&AE 212(2120) Mechanical Properties and Selection of Engineering Materials

Spring; may be offered in summer. 3 credits. Prerequisites: ENGRD/T&AM 202 (Statics) with minimum of C– (strictly enforced); MATLAB programming at level of CS 100 M or CS 101 M. Software fee.

Mechanics of deformable bodies and a reinforcement of the concept of "simple engineering elements" for mechanical analysis associated with design. Introduction to the broad range of properties and behaviors of engineering materials as they relate to mechanical performance. Emphasis is placed on general states of stress and strain, on elasticity and combined loading effects. Failure criteria including yielding, buckling, fracture, fatigue and environmental effects are developed. A general introduction to the function/constraints/objectives approach to material selection associated with mechanical design is provided with candidate material systems coming from metals, polymers, ceramics and/or composites. A general overview of material processing is presented within this context of material selection.

M&AE 221(2210) Thermodynamics (also ENGRD 221[2210])

Fall, spring, may be offered in summer. 3 credits. Prerequisites: MATH 192 and PHYS 112 or permission of instructor.

For description, see ENGRD 221.

M&AE 225(2250) Mechanical Synthesis

Spring. 4 credits. Prerequisite: ENGRD 202. Pre- or corequisites: ENGRD 203 and 221. Lab fee.

Hands-on introduction to the product design process, from conceptualization through prototype construction and testing. Design projects provide experience in basic prototyping skills using machine tools. Mechanical dissection used to demonstrate successful product design and function. Basic instruction on CAD and technical sketching.

M&AE 305(3050) Introduction to Aeronautics

Fall. 3 credits. Prerequisite: T&AM/ENGRD 203. Pre- or corequisites: one of the following thermodynamics classes: ENGRD 221 or BEE 222 and one of the following fluid mechanics classes: M&AE 323 or CHEME 323 or BEE 331 or CEE 331; upperclass engineers or permission of instructor.

Introduction to aerodynamic design of aircraft. Principles of incompressible and compressible aerodynamics, boundary layers, and wing theory. Calculation of lift and drag for aircraft.

Analysis of aerodynamic performance. Introduction to stability and control.

M&AE 306(3060) Spacecraft Engineering
Spring. 3 credits. Prerequisite: ENGRD 203 or junior or senior M&AE or ECE students or permission of instructor.
Introduction to spacecraft engineering from satellite design through launch to orbital operation. Topics covered include space missions, space environment, orbital mechanics, systems engineering, and satellite design. Most spacecraft subsystems are introduced including rocket theory, attitude determination and control, thermal design, and communications. Earth-orbiting and interplanetary satellites are considered. Discussions of current problems and trends in spacecraft operation and development.

M&AE 312(3120) Mechanical Properties of Materials, Processing, and Design (also MS&E 402[4020], 582[5820])
Fall. 4 credits.
For description, see MS&E 402.

M&AE 313(3130) Atomic and Molecular Structure of Matter (also MS&E 206[2060], MS&E 581[5810])
Spring. 4 credits.
For description, see MS&E 206.

M&AE 323(3230) Introductory Fluid Mechanics
Fall; usually offered in summer through Engineering Cooperative Program. 4 credits. Prerequisites: ENGRD 202 and ENGRD 203 and pre- or co-registration in ENGRD 221, or permission of instructor. Limited to ME majors and those officially registered for the AE or ME minor.
Topics include physical properties of fluids, hydrostatics, conservation laws using control volume analysis and using differential analysis, Bernoulli's equation, potential flows, simple viscous flows (solved with Navier-Stokes equations), dimensional analysis, pipe flows, boundary layers. Introduction to compressible flow.

M&AE 324(3240) Heat Transfer
Spring; usually offered in summer through Engineering Cooperative Program. 3 credits. Prerequisite: M&AE 323 or permission of instructor.
Topics include discussion of steady and unsteady heat conduction; forced and free convection; external and internal flows; radiation heat exchange; and heat exchangers and boiling.

M&AE 325(3250) Analysis of Mechanical and Aerospace Structures
Fall; usually offered in summer through Engineering Cooperative Program. 3 credits. Prerequisites: ENGRD 202 and M&AE 212.
Topics in mechanics of materials applied to analysis and design of structural components encountered in mechanical and aerospace systems, including multiaxial stress states, statically indeterminate structures, torsion and bending of nonsymmetric or curved members, stability and stress concentrations. Solution strategies include both analytical and finite element methods.

M&AE 326(3260) System Dynamics
Spring; usually offered in summer through Engineering Cooperative Program. 4 credits. Prerequisite: MATH 294, ENGRD 203. Junior standing required.
Dynamic behavior of mechanical systems: modeling, analysis techniques, and applications; vibrations of single- and multi-degree-of-freedom systems; feedback control systems. Computer simulation and experimental studies of vibration and control systems.

M&AE 327(3272) Mechanical Property and Performance Laboratory
Spring. 2 credits. Prerequisites: M&AE 212, 325.
This course provides an introduction to the experimental methods, instrumentation, and data analyses associated with material property determination and mechanical performance of materials. Emphasis is placed on integration of theory and analysis with experimental methods.

M&AE 378(3780) Mechatronics
Fall. 3 credits. Prerequisite: MATH 293, PHYS 213, or permission of instructor.
At the intersection of mechanical and electrical engineering, Mechatronics involves technologies necessary to create automated systems. This course introduces students to the functional elements of modern controlled dynamic systems. Topics include analog circuits (both passive and active components); filter design; diodes; transistors, MOSFETs and power amplification; pulse width modulation; transduction; mechanical and electro-mechanical devices such as electromagnetic systems; piezoelectric and shape memory material transduction; gear trains; optical encoders; discretization; aliasing; and microprocessors and programming. Lab experiments culminate in the design, fabrication, and programming of a microprocessor-controlled robotic vehicle, which laboratory groups enter into a class-wide competition.

[M&AE 400(4001) Components and Systems: Engineering in a Social Context (also S&TS 400[4001])
Spring. 3 credits. Prerequisites: upper-class standing, two years of college physics. Offered alternate years; next offered 2008–2009.
Addresses, at a technical level, broader questions than are normally posed in the traditional engineering or physics curriculum. Through the study of individual cases such as the Strategic Defense Initiative (SDI), the National Missile Defense, supersonic transport, and the automobile and its effect on the environment, the course investigates interactions between the scientific, technical, political, economic, and social forces that are involved in the development of engineering systems. "Senior Design Elective" if students sign up for the corresponding section of M&AE 429. Co-meets with M&AE 500.]

M&AE 415(4150) GPS: Theory and Design (also ECE 415[4150])
Fall. 4 credits. Prerequisites: 300-level engineering course with advanced math content (e.g., ECE 303 or M&AE 326).
For description, see ECE 415.

M&AE 417(4170) Introduction to Robotics: Dynamics, Control, Design
Spring. 3 credits. Prerequisites: engineering math at level of MATH 293 and MATH 294 (Engineering Mathematics); some course in dynamics at level of T&AM/ENGRD 203 (Dynamics); familiarity with control concepts typical of M&AE 326 (System Dynamics).
Introductory course in the analysis and control of mechanical manipulators and related robotic machines. Topics include spatial descriptions and transformations, manipulator kinematics and inverse kinematics, differential relationships and static forces, manipulator dynamics, trajectory generation, sensors and actuators, trajectory control, and compliant motion control. Simulation and design using MATLAB and multi-body codes are used. Co-meets with M&AE 517.

M&AE 423(4231) Intermediate Fluid Dynamics
Spring. 3 credits. Prerequisite: M&AE 323 (Introductory Fluid Mechanics) or CEE 331/ BEE 331, CHEME 323 or permission of instructor.
This course builds on the foundation of M&AE 323. Emphasis is placed on both the fundamental principles and numerical calculation of real flows (both engineering and environmental) using a computational fluid dynamics package. Topics covered include some exact solutions to the Navier-Stokes equations, boundary layers, wakes and jets, separation, convection, fluid instabilities, and turbulence. "Senior Design Elective" if students sign up for the corresponding section of M&AE 429. Co-meets with M&AE 523.

M&AE 425(4251) FSAE Automotive Design Project
Fall, spring. Usually 3 credits: 3 for team members or 4 for team leaders. Prerequisite: M&AE or ECE juniors and seniors or permission of instructor.
Project course to research, design, build, develop, and compete with a Formula SAE car for intercollegiate competition. Students work in interdisciplinary teams using concurrent engineering and systems engineering principles applied to complex mechanical, electromechanical, and electronic systems. "Senior Design Elective" if students sign up for the corresponding section of M&AE 429.

M&AE 427(4272) Fluids/Heat Transfer Laboratory
Fall. 3 credits. Fulfills technical-writing requirement. Prerequisites: M&AE 323, 324.
Laboratory exercises in fluid mechanics and the thermal sciences. Measurements of flame temperature, pressure, heat transfer, viscosity, lift and drag, fluid-flow rate, effects of turbulence, air foil stall, flow visualization, and spark ignition engine performance. Instrumentation, techniques and analysis, and interpretation of results. Biweekly written assignments with extensive feedback.

M&AE 428(4280) Engineering Design
Fall. 2 credits. Prerequisite: senior standing or permission of instructor.
This course is offered to illustrate and practice the design "process." It consists of formal lectures and invited seminars by industrial and academic practitioners of design. Case studies are presented in weekly invited lectures from a wide range of disciplines, including thermo-fluid processes, manufacturing, energy, mechanical design, aerospace, and biological sciences. The invited lectures are supplemented by one or more design "projects" in the semester.

M&AE 429(4291) Supervised Senior Design Experience
Fall, spring. Minimum of 1 or 3 credits depending on section chosen. Prerequisite: senior standing or permission of instructor; taken concurrently or after M&AE 428. Letter grades only.

Substantial design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints. Sections of this course satisfy the BS ME senior design requirement. They are offered in conjunction with a course designated as "Senior Design Elective" (M&AE 400, 423, 425, 470, 479, 486) or are directed by a faculty member as an individual or a team design exercise. Consult www.mae.cornell.edu for enrollment details.

[M&AE 449(4490) Combustion Engines and Fuel Cells

Spring. 3 credits. Prerequisites: ENGRD 221 and M&AE 323. Offered alternate years; Next offered 2008–2009.

Introduction to reciprocating combustion engines and fuel cells, with emphasis on the application of thermodynamic and fluid-dynamic principles affecting their performance. Chemical equilibrium and kinetics, electrochemistry, thermodynamic limits on performance, deviations from ideal processes, engine breathing, combustion, knock. Formation and control of undesirable exhaust emissions.]

M&AE 453(4530) Computer-Aided Engineering: Applications to Biomedical Processes (also BEE 453[4530])

Spring. 3 credits. Fulfills technical elective requirement for M&AE students. Prerequisite: Heat and Mass Transfer (BEE 350, Biological and Environmental Transport Processes, or CHEME 324, Heat and Mass Transfer, or M&AE 324, Heat Transfer, or equivalent.

For description, see BEE 453.

M&AE 455(4550) Introduction to Composite Materials (also CEE 477[4770], MS&E 555[5550], T&AM 455[4550])

Fall. 4 credits.

For description, see T&AM 455.

M&AE 458(4580) Introduction to Nuclear Science and Engineering (also ECE 413[4130], T&AM 413[4130])

Fall. 3 credits. Prerequisites: PHYS 214 and MATH 294

For description, see T&AM 413.

M&AE 459(4590) Introduction to Controlled Fusion: Principles and Technology (also ECE 484[4840], A&EP 484[4840])

Spring. 3 credits. Prerequisites: PHYS 112, 213, and 214, or equivalent background in electricity and magnetism and mechanics. Intended for seniors and graduate students in engineering and the physical sciences. Offered alternate years.

For description, see ECE 484.

M&AE 461(4610) Entrepreneurship for Engineers (also ENGRG 461[4610], OR&IE 452[4520])

Fall. 3 credits. Limited enrollment. Prerequisite: enrollment open to upper-class engineers or permission of instructor.

Develops skills necessary to identify, evaluate, and begin new business ventures. Topics include intellectual property, competition, strategy, business plans, technology forecasting, finance and accounting, and sources of capital. A rigorous, quantitative approach is stressed throughout, and students create financial documents and plans, analyze human resource models, and work with sophisticated valuation methods, complicated equity structures, and legal and business documents. As such, this course represents the "red meat" of entrepreneurship, and the soft skills are left for other courses. Course work consists of discussions, assignments, and the preparation and presentation of a complete business plan.

[M&AE 463(4630) Neuromuscular Biomechanics (also BME 463[4630])]

M&AE 464(4640) Orthopaedic Tissue Mechanics

Spring. 3 credits. Prerequisites: ENGRD 202 Mechanics of Solids and M&AE 325 Mechanical Design and Analysis or permission of instructor. Offered alternate years.

Applications of mechanics and materials principles to orthopaedic tissues. Physiology of bone, cartilage, ligament, and tendon and how these properties relate to mechanical function. Mechanical behavior of skeletal tissues in the laboratory. Functional adaptation of these tissues to their mechanical environment. Tissue engineering of replacement structures.

M&AE 466(4660) Biomedical Engineering Analysis of Metabolic and Structural Systems (also BME 401[4010])

Fall. 3 credits. Prerequisites: ENGRD 202 Mechanics of Solids and previous course work in biology or permission of instructor.

For description, see BME 401.

M&AE 470(4701) Finite Element Analysis for Mechanical and Aerospace Design

Spring. 3 credits. Fulfills senior design requirement for M&AE students. Limited enrollment. Prerequisite: senior standing or permission of instructor. Evening exams. Term project.

Introduction to linear finite element static and dynamic analysis for discrete and distributed mechanical and aerospace structures. Prediction of load, deflection, stress, strain, and temperature distributions. Major emphasis on underlying mechanics and numerical methods. Introduction to computational aspects via educational and commercial software (such as MATLAB and ANSYS). Selected mechanical and aerospace applications in the areas of trusses, beams, frames, heat transfer (steady state and transient), and elasticity (static and dynamic). Term project. "Senior Design Elective" if students sign up for the corresponding section of M&AE 429. Co-meets with M&AE 570.

M&AE 473(4730) Practicum in Artificial Intelligence

Fall: 2 credits. Corequisite: CS 472.

For description, see CS 473.

M&AE 477(4770) Engineering Vibrations

Spring. 3 credits. Pre- or corequisite: M&AE 326 or permission of instructor.

Lumped element, distributed parameter, and mixed structural vibratory systems are examined. Equations of motion are derived from Newton's law and Lagrange's equations. Eigenanalysis, free and forced responses, and frequency/time domain solutions are considered. Vibration absorbers, isolators, and vibration suppression control systems using feedback approaches also are investigated. Co-meets with M&AE 577.

M&AE 478(4780) Feedback Control Systems (also CHEME 472[4720], ECE 472[4720])

Fall. 4 credits. Prerequisites: CHEM E 372 or M&AE 326 or permission of instructor.

Analysis techniques, performance specifications, and analog-feedback-compensation methods for single-input, single-output, linear, time-invariant systems. Laplace transforms and transfer functions are the principal mathematical tools. Design techniques include root-locus and frequency response methods. Includes laboratory that examines modeling and control of representative dynamic processes. Co-meets with M&AE 578.

[M&AE 479(4791) Modeling and Simulation of Mechanical and Aerospace Systems

Fall. 4 credits, variable. Limited enrollment. Prerequisite: seniors in engineering or permission of instructor. Evening exams. Next offered 2008–2009.

Analysis and simulation of linear and nonlinear systems. Representation of discrete and distributed dynamical systems by state-variable models. Time- and frequency-domain simulation via general-purpose languages (such as MATLAB or Mathematica) and special-purpose simulation software (such as Simulink). Selected applications from diverse fields. Term project. "Senior Design Elective" if students sign up for the corresponding section of M&AE 429. Co-meets with M&AE 579.]

M&AE 486(4861) Automotive Engineering

Fall. 3 credits. Prerequisites: ENGRD 202 or permission of instructor.

Selected topics in the analysis and design of vehicle components and vehicle systems. Emphasis on automobiles. Engines, transmissions, suspension, brakes, and aerodynamics will be discussed. The course uses first principles and applies them to specific systems. The course is highly quantitative, using empirical and analytical approaches. "Senior Design Elective" if students sign up for the corresponding section of M&AE 429.

M&AE 490(4900) Special Investigations in Mechanical and Aerospace Engineering

Fall, spring. 4 variable credits. Prerequisite: undergraduate standing and permission of instructor.

Intended for an individual student or a small group of students who want to pursue a particular analytical or experimental investigation outside of regular courses or for informal instruction supplementing that given in regular courses.

M&AE 498(4980) Teaching Experience in Mechanical Engineering

Fall, spring. 3 variable credits. Prerequisite: permission of instructor.

Students serve as teaching assistants in Cornell mechanical engineering classes or in local middle school technology classes. Cannot be used to fulfill M.E. technical elective or M.E. major elective requirements but may be approved as advisor-approved elective. May not be used toward satisfying M.E. minor.

[M&AE 500(5000) Components and Systems: Engineering in a Social Context

Spring. 3 credits. Prerequisites: graduate standing or permission of instructor, two

years of college physics. Offered alternate years; next offered 2008–2009.
Co-meets with M&AE 400. For description, see M&AE 400.]

M&AE 501(5010) Future Energy Systems
Spring. 3 credits. Prerequisites: ENGRD 221 (Thermodynamics) or equivalent. Recommended: M&AE 323 (Introductory Fluid Mechanics), M&AE 324 (Heat Transfer), or equivalents; open to graduate or senior standing or permission of instructor.
Critically examines the technology of energy systems that will be acceptable in a world faced with global climate change, local pollution, and declining supplies of oil. The focus is on renewable energy sources (wind, solar, biomass), but other non-carbon-emitting sources (nuclear) and lowered-carbon sources (co-generative gas turbine plants, fuel cells) also are studied. Both the devices and the overall systems are analyzed.

M&AE 506(5060) Aerospace Propulsion Systems
Spring. 3 credits. Prerequisite: M&AE 305 (Introduction to Aeronautics) or permission of instructor. Offered alternate years.
Application of thermodynamic and fluid-mechanical principles to design and performance analysis of aerospace propulsion systems. Jet propulsion principles, including gas turbine engines and rockets. Electric propulsion. Future possibilities for improved performance of aerospace propulsion systems.

[M&AE 507(5070) Dynamics of Flight Vehicles
Spring. 3 credits. Prerequisites: M&AE 305 (Introduction to Aeronautics) and M&AE 326 (System Dynamics) or permission of instructor. Offered alternate years; next offered 2008–2009.
Introduction to stability and control of atmospheric-flight vehicles. Review of aerodynamic forces and methods for analysis of linear systems. Static stability and control. Small disturbance equations of unsteady motion. Dynamic stability of longitudinal and lateral-directional motions; transient response. At the level of *Flight: Stability and Automatic Control* by Nelson.]

[M&AE 513(5130) Mechanical Properties of Thin Films (also MS&E 512[5120])
Spring. 3 credits. Offered alternate years; next offered 2008–2009.
For description, see MS&E 512.]

M&AE 517(5170) Introduction to Robotics: Dynamics, Control, Design
Spring. 3 credits. Graduate version of M&AE 417. Co-meets with M&AE 417.
For description, see M&AE 417.

M&AE 520(5200) Dimensional Tolerancing in Mechanical Design
Fall. 2 credits. Seven-week half term. Prerequisites: M&AE 225 or an equivalent CAD-based design course, plus 2.5 years of engineering mathematics through probability and statistics.
Mechanical parts vary in size and shape. Designers use dimensional tolerances to control spatial variability and thus ensure that parts function properly and can be assembled into products.The course covers traditional limit tolerances briefly but focuses mainly on modern geometric tolerances. Students learn how to interpret tolerance specifications, assign tolerance values in simple applications, and assess the limitations and probable future directions of tolerancing technology.

M&AE 521(5210) Theory of Linear Systems (also ECE 521[5210])
Fall. 3 credits. Prerequisites: M&AE 326 or ECE 320 or permission of instructor. Recommended: good background in linear algebra and linear differential equations.
For description, see ECE 521.

M&AE 523(5230) Intermediate Fluid Dynamics
Spring. 4 credits. Prerequisite: graduate standing or permission of instructor.
Intended for M.Eng. students who wish to take a fluid dynamics course including implementation of commercial computational fluid dynamics packages. Complements material in MAE 601 and 602. For description of topics covered, see M&AE 423. Includes a 1-credit CFD design project due at the end of the semester. Students desiring to write their own computational fluid dynamics software should consider one or more of M&AE 636, 736, and 737. Co-meets with M&AE 423.

M&AE 524(5240) Physics of Micro- and Nanoscale Fluid Mechanics (also CHEME 524[5240])
Fall. 3 credits. Prerequisite: undergraduate fluid or continuum mechanics (e.g., M&AE 323) or permission of instructor.
Introduction to fluid mechanics in micro- and nanofabricated devices. Physicochemical hydrodynamics, electrokinetic effects, capillarity, continuum breakdown, micro- and nanofluidic applications in chemistry and life sciences. Co-meets with M&AE 624.

M&AE 543(5430) Combustion Processes
Fall. 3 credits. Prerequisite: graduate standing or permission of instructor.
An introduction to combustion and flame processes, with emphasis on fundamental fluid dynamics, heat and mass transport, and reaction-kinetic processes that govern combustion rates. Topics covered include thermochemistry, kinetics, vessel explosions, laminar premixed and diffusion flames, and droplet combustion. Optional topics may include complex combustion systems, turbulent flames, fuel cells, or combustion of solids.

M&AE 545(5459) Energy Seminar I (also ECE 587[5870])
Fall. 1 credit.
For description, see ECE 587.

M&AE 546(5469) Energy Seminar II (also ECE 588[5880])
Spring. 1 credit.
For description, see ECE 588.

[M&AE 563(5630) Neuromuscular Biomechanics]

[M&AE 565(5650) Biomechanical Systems—Analysis and Design (also BME 565[5650])]

M&AE 570(5700) Finite Element Analysis for Mechanical and Aerospace Design
Spring. 4 credits. Prerequisite: graduate standing or permission of instructor. Evening exams. Term project. Graduate version of M&AE 470 requires additional programming assignment. Co-meets with M&AE 470.
For description, see M&AE 470.

[M&AE 571(5710) Applied Dynamics
Fall. 3 credits. Prerequisites: graduate standing, seniors with ENGRD/T&AM 203, M&AE 326 or permission of instructor. Next offered 2008–2009.
Introduces multibody dynamics; dynamics of rigid bodies; Newton-Euler methods, Lagrangian dynamics, principle of virtual power (Kane-Jourdain methods); and applications to robotics, space dynamics of satellites, electro-mechanical systems. Introduction to multibody simulation using Working Model.]

M&AE 577(5770) Engineering Vibrations
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor. Graduate version of M&AE 477. Co-meets with M&AE 477.
For description, see M&AE 477.

M&AE 578(5780) Feedback Control Systems
Fall. 4 credits. Graduate version of M&AE 478. Co-meets with M&AE 478.
For description, see M&AE 478.

[M&AE 579(5790) Modeling and Simulation of Mechanical and Aerospace Systems
Fall. 4 credits. Limited enrollment. Prerequisite: graduate standing or permission of instructor. Evening exams. Graduate version of M&AE 479. Term project. Co-meets with M&AE 479. Next offered 2008–2009.
For description, see M&AE 479.]

M&AE 591(5910) Applied Systems Engineering (also CEE 504[5040], CS 504[5040], ECE 512[5120], OR&IE 512[5120], SYSEN 510[5100])
Fall. 3 credits. Prerequisites: senior or graduate standing in engineering field; concurrent or recent (past two years) enrollment in a group-based project with a strong system design component that is approved by course instructor.
For description, see SYSEN 510.

M&AE 592(5920) System Architecture, Behavior, and Optimization (also CEE 505[5050], CS 505[5050], ECE 513[5130], OR&IE 513[5142], SYSEN 520[5200])
Spring. 3 credits. Prerequisites: senior or graduate standing and completion of Applied Systems Engineering 1 (CEE 504, CIS 504, ECE 512, OR&IE 512, M&AE 591, or SYSEN 510) or permission of instructor.
For description, see SYSEN 520.

M&AE 593(5930) Systems Engineering for the Design and Operation of Reliable Systems
Fall. 3 credits. Prerequisites: M&AE 591 and either OR&IE 270 or CEE 304.
For description, see SYSEN 530.

M&AE 594(5949) Enterprise Engineering Colloquium (also OR&IE 893–894[8930–8940])
Fall, spring. 1 credit each semester. Usually S-U grades.
For description, see OR&IE 893–894.

M&AE 601(6010) Foundations of Fluid Dynamics and Aerodynamics
Fall. 4 credits. Prerequisite: graduate standing or permission of instructor.
Foundations of fluid mechanics from an advanced viewpoint, including formulation of continuum fluid dynamics; surface phenomena and boundary conditions at interfaces;

fundamental kinematic descriptions of fluid flow, tensor analysis, derivation of the Navier-Stokes equations and energy equation for compressible fluids; and sound waves, viscous flows, boundary layers, and potential flows.

M&AE 602(6020) Fluid Dynamics at High Reynolds Numbers

Spring. 4 credits. Prerequisite: M&AE 601.

Analysis and discussion of a wide range of specific flows and flow regimes characterized by high Reynolds number are provided. Potential flows, conformal transformations, slender-body theory, and Kelvin's impulse are included. Laminar viscous flows are studied, including fully diffused flows, "exact" solutions, and boundary layers. Compressible flows are treated, including propagation and viscous decay of sound and shock waves and their decay, and the method of characteristics for analysis of such problems. Stratified flows, especially gravity and capillary waves, are analyzed. Various stability problems associated with high Reynolds number flows are discussed. Finally, certain low Reynolds number flows associated with creeping motions or with ultra-small scale are described.

[M&AE 606(6060) Spacecraft Dynamics and Mission Design

Spring. 3 credits, Prerequisites: graduate standing or permission of instructor; background in linear algebra at level of MATH 294 is required; some experience with MATLAB is expected. Offered alternate years; next offered 2008–2009.

The focus is on spacecraft attitude dynamics and its application in core space-systems areas: mission design, operations, and autonomy. Also introduces the problem of attitude estimation and treats aspects of guidance, navigation, and control unique to the context of space mission design. Readings and lectures include examples based on flight data.]

M&AE 608(6080) Physics of Fluids

Spring. 4 credits. Prerequisite: graduate standing or permission of instructor. Offered alternate years.

Behavior of an ideal gas is considered at the microscopic level. Introduction to kinetic theory—the velocity distribution function, molecular collisions, and Boltzmann equation; to quantum theory—postulates of quantum mechanics, rigid rotator, harmonic oscillator, one-electron and multi-electron atoms and molecular structure; and to statistical mechanics—the partition function, relation to thermodynamics, calculations of thermodynamic properties.

M&AE 624(6240) Physics of Micro- and Nanoscale Fluid Mechanics and Heat Transfer

Fall. 4 credits. Pre- or corequisite: undergraduate fluid or continuum mechanics (e.g., M&AE 323) or permission of instructor. Graduate version of M&AE 524. Includes additional 1-credit design project. Co-meets with M&AE 524.

For description, see M&AE 524.

M&AE 627(6270) Experimental Methods in Fluid Dynamics (also CEE 637[6370]

Spring. 4 credits. E. A. Cowen.

For description, see CEE 637.

M&AE 631(6310) Turbulence and Turbulent Flows

Fall. 4 credits. Prerequisite: M&AE 601 (Foundations of Fluid Dynamics and Aerodynamics), graduate standing, or permission of instructor.

Topics include the dynamics of buoyancy and shear-driven turbulence, boundary-free and bounded shear flows, second-order modeling, the statistical description of turbulence, turbulent transport, and spectral dynamics.

[M&AE 632(6320) Multiphase Turbulence: Particulates, Drops, and Polymer Suspensions]

[M&AE 636(6360) Elements of Computational Aerodynamics]

M&AE 643(6430) Computational Combustion

Spring. 4 credits. Prerequisite: graduate standing or permission of instructor. Offered alternate years. S. B. Pope.

Examines laminar and turbulent flames and the fundamental chemical and transport processes involved. Emphasis is on using computational tools (Chemkin and Fluent) to calculate flame properties, which are compared to experimental data. Topics covered include thermodynamic equilibrium, chemical kinetics, reactor studies, conservation equations, transport properties, laminar premixed and non-premixed flames, turbulent jets, turbulence modeling, and PDF models of non-premixed turbulent combustion. A knowledge of combustion at the level of M&AE 543, Combustion Processes, is useful but not required.

[M&AE 645(6450) Turbulent Reactive Flow

Spring. 4 credits. Prerequisite: graduate standing or permission of instructor. Offered alternate years; Next offered 2008–2009.

Large turbulent reactive flows occur in combustion devices, the chemical process industry, the atmosphere, oceans, and elsewhere. In the last decade, substantial progress has been made in the understanding of these flows, through both experimental and computational approaches. This course focuses on turbulent combustion and describes the different phenomena involved, the basic processes and governing equations, experimental techniques and observations, and a range of modeling approaches. Class meets, on average, twice per week.]

M&AE 648(6480) Air Quality and Atmospheric Chemistry (also EAS 648[6480])

Fall. 3 credits. Prerequisites: first-year chemistry and thermodynamics (or equivalent) and fluid mechanics (or equivalent); graduate standing or permission of instructor.

Factors determining air quality and effects of air pollutants on public health, ecological systems and global climate change. Students will examine the source-to-receptor relationship of major air pollutants with an emphasis on the physical and chemical fundamentals of atmospheric transport and transformation. Topics include photochemical smog, atmospheric aerosols, atmospheric transport and deposition, emissions from energy systems, introduction to air quality monitoring and modeling, and air quality management.

[M&AE 650(6500) Evolutionary Computation and Design Automation (also CS 750[7500])

Fall. 4 credits. Not offered every year; next offered 2008–2009.

For description, see CS 750.]

M&AE 651(6510) Conduction and Radiation Heat Transfer

Fall, weeks 1–7. 2 credits. Prerequisite: graduate standing; undergraduates by permission of instructor.

An advanced treatment of heat conduction and thermal radiation from a theoretical perspective. Topics include: development of the conductive transport equation in integral and differential forms; the transport theorem; solutions for steady state and transient conditions; moving boundary effects including melting and solidification; introduction to radiation including black body and gray body radiation, the radiative transport equation and radiation in an absorbing and scattering medium. At the level of *Conduction Heat Transfer*, by V. Arpaci, and *Radiation Heat Transfer*, by E. M. Sparrow and R. D. Cess.

M&AE 652(6520) Convection Heat Transfer

Fall, weeks 8–14. 2 credits. Prerequisite: graduate standing; undergraduates by permission of instructor.

An advanced treatment of convection heat transfer from a theoretical perspective. Topics include: conservation of linear momentum in integral and differential forms; boundary layer flows with emphasis on laminar conditions (some introduction to turbulence also included); internal and external flows; forced and free convection; theoretical solutions and scale analysis. At the level of *Convection Heat Transfer*, by A. Bejan, and *Convective Heat and Mass Transfer*, by W. M. Kays et al.

M&AE 655(6550) Composite Materials (also T&AM 655[6550], MS&E 655[6550])

Spring. 4 credits.

For description, see T&AM 655.

M&AE 656(6560) Nanoscale Energy Transport and Conversion

Spring. 4 credits. Prerequisites: undergraduate heat transfer recommended (e.g., M&AE 324) or permission of instructor. Offered alternate years.

This course aims to provide a detailed look at thermal, electrical, and optical energy transport and conversion mechanisms at the nanoscale. Topics to be covered include: a brief review of macroscopic heat transfer with emphasis on limits of macroscopic models, microscopic picture of energy carriers, material waves, energy quantization and energy states in solids, statistical thermodynamics and probability distribution functions as related to thermal energy storage, energy transport by waves and classical particle descriptions of transport processes and energy conversion and exchange processes between carriers. Emphasis will be put on practical applications and nanoengineering principles including heat transfer in nanoelectronics, nanophotonic and nanofluidic devices and nanostructured energy conversion devices.

M&AE 663(6630) Neural Control (also BME 663[6630])]

[M&AE 664(6640) Mechanics of Bone (also BME 664[6640])

Spring. 3 credits. Prerequisite: graduate standing or permission of instructor. Offered alternate years; next offered 2008–2009.

Covers current methods and results in skeletal research, focusing on bone. Topics include skeletal anatomy and physiology, experimental and analytical methods for determination of skeletal behavior, mechanical behavior of bone tissue, and skeletal functional adaptation to mechanics.]

M&AE 665(6650) Principles of Tissue Engineering (also BME 665[6650], MS&E 665[6650])

Spring. 3 credits. Prerequisite: graduate standing or permission of instructor. L. Bonassar.

For description, see BME 665.

[M&AE 675(6750) System Identification and Control]

M&AE 676(6760) Model-Based Estimation

Spring. 4 credits. Prerequisites: linear algebra, differential equations, and MATLAB programming. Open to M.S./Ph. D. students or permission of instructor. Offered alternate years.

Covers a variety of ways in which models and experimental data can be used to estimate model quantities that are not directly measured. The two main estimation methods that are presented are least-squares estimation for general problems and Kalman filtering for dynamic systems problems. Techniques for linear models are taught as are techniques for nonlinear models. Both theory and application are presented.

[M&AE 678(6780) Multivariable Control Theory

Spring, 4 credits. Prerequisites: M&AE 478 or 578 or ECE 472 (Feedback Control Systems) and M&AE 521 (Theory of Linear Systems), or permission of instructor; strong background in classical control, linear algebra, and state space models. Next offered 2008–2009.

Introduction to multivariable feedback control theory in both time and frequency domain. Primary topics include state space methods, model based compensators, performance and robustness of multivariable systems, model reduction, Linear Quadratic and H-infinity optimal control, and random processes and Kalman filtering for control. Additional topics at the discretion of the instructor include uncertainty management and robust control, discrete time control, optimal control, and nonlinear control.]

M&AE 690(6901) Special Investigations in Mechanical and Aerospace Engineering

Fall, spring. Variable credit. Prerequisite: candidacy for the M.Eng. degree in mechanical or aerospace engineering or approval of faculty member offering project.

Project-based course in the area of mechanical or aerospace engineering under the guidance of a faculty member.

M&AE 695(6950) Special Topics in Mechanical and Aerospace Engineering

Fall, spring. Credit TBA. Prerequisites: graduate standing and permission of instructor.

Special lectures by faculty members on topics of current research.

[M&AE 711(7110) X-Ray Diffraction Methods for Engineering Materials

Fall. 4 credits. Prerequisites: graduate standing or permission of instructor. Next offered 2008–2009.

We develop a general understanding of diffraction methods employed for understanding the state of crystalline materials. The focus will be on x-ray diffraction and the determination of crystal orientation and lattice strains. We conduct diffraction experiments at the CCMR x-ray facility and examine synchrotron x-ray data. We develop MATLAB-based methods for reducing diffraction data and extracting distributions of orientation and lattice strain.]

[M&AE 712(7120) Mechanics of Materials with Oriented Microstructures

Spring. 4 credits. Prerequisites: T&AM 663 or equivalents. Offered alternate years; next offered 2008–2009.

The focus of this course is the evaluation of mechanical properties from knowledge of the material microstructure, with attention to anisotropic elastic and plastic behaviors. Topics include mathematical and mechanics preliminaries; mathematical foundations of orientations, including parameterizations, symmetries, and fibers; construction and sampling of orientation distributions; hypotheses used to link macro and micro length scales; methods for evaluation of effective elastic and plastic moduli; evolution of orientations and orientation distributions with deformation. Applications to polycrystalline solids (metal alloys and minerals), composite materials, biomaterials (soft tissues), and polymers.]

[M&AE 714(7140) Computational Sensorics: Information Technologies for Complex Continuum Systems

Fall. 4 credits. Prerequisite: exposure to computational mathematics. Next offered 2008–2009.

Examples of industrial control of continuum systems; mathematical preliminaries; data-driven inverse problems; data mining and knowledge discovery in continuum systems; Bayesian computation; optimal and robust control; model reduction; uncertainty modeling and stochastic optimization; Sensors and sensor-networks.]

M&AE 715(7150) Atomistic Modeling of Materials

Spring. 4 credits. Prerequisite: graduate standing or permission of instructor.

Intended for graduate students in engineering, physics, and chemistry with interests in the simulation of materials at the atomic scale using academic and commercial software. Emphasis is given to models of interatomic forces from Lennard-Jones models to self-consistent all-electron solution of the quantum mechanical problem. Specific topics include: energy models, density functional theory and the total-energy pseudopotential method, Monte Carlo and molecular dynamics simulations, free energy and phase transitions, fluctuations and transport properties, first-principles MD, Ab-initio thermodynamics and structure prediction, coarse-graining methods and mesoscale models. The course includes advanced applications of materials to nanotechnology. The material covered is self-contained, but an earlier exposure to quantum mechanics and solid state physics is desirable.

[M&AE 734(7340) Analysis of Turbulent Flows

Spring. 4 credits. Prerequisite: M&AE 601 Foundations of Fluid Dynamics and Aerodynamics or permission of instructor. Offered alternate years; next offered 2008–2009.

Study of methods for calculating the properties of turbulent flows. Characteristics of turbulent flows. Direct numerical simulations and the closure problem. Reynolds-stress equation: effects of dissipation, anisotropy, deformation. Transported scalars. Probability density functions (pdfs): transport equations, relationship to second-order closures, stochastic modeling, and the Langevin equation. Large-eddy simulations: filtered and residual motions, Smagorinsky, and dynamic models. This course emphasizes comparison of theory with experiment and includes CFD projects.]

[M&AE 736(7360) Theory of Computational Aerodynamics]

M&AE 737(7370) Computational Fluid Mechanics and Heat Transfer

Fall. 4 credits. Prerequisites: graduate standing; advanced course in continuum mechanics, heat transfer, or fluid mechanics; and some MATLAB, C++, or other programming experience.

Numerical methods are developed for the elliptic and parabolic partial differential equations that arise in fluid flow and heat transfer when convection and diffusion are present. Finite-difference, finite-volume, and some spectral methods are considered, together with issues of accuracy, stability, convergence, and conservation. Current methods are reviewed. Emphasis is on steady and unsteady essentially incompressible flows. Assigned problems are solved on a digital computer.

M&AE 791(7910) Mechanical and Aerospace Research Conference

Fall, spring. 1 credit each semester. For graduate students involved in research projects. S-U grades only.

Presentations on research in progress by faculty and students.

M&AE 799(7999) Mechanical and Aerospace Engineering Colloquium

Fall, spring. 1 credit each semester; credit limited to graduate students. All students and staff are invited to attend.

Lectures by visiting scientists and Cornell faculty and staff members on research topics of current interest in mechanical and aerospace science, especially in connection with new research.

M&AE 890(8900) Research in Mechanical and Aerospace Engineering

Credit TBA. Prerequisite: candidacy for M. S. degree in mechanical or aerospace engineering or approval from director.

Independent research in an area of mechanical and aerospace engineering under the guidance of a member of the faculty.

M&AE 990(9900) Research in Mechanical and Aerospace Engineering

Credit TBA. Prerequisite: candidacy for Ph.D. degree in mechanical or aerospace engineering or approval from director.

Independent research in an area of mechanical and aerospace engineering under the guidance of a member of the faculty.

NUCLEAR SCIENCE AND ENGINEERING

Faculty members in the graduate field of nuclear science and engineering who are most directly concerned with the curriculum include K. B. Cady, D. A. Hammer, R. W. Kay, and V. O. Kostroun.

NS&E 484(4840) Introduction to Controlled Fusion: Principles and Technology (also A&EP/ECE 484[4840], M&AE 459[4590])
Spring. 3 credits. Prerequisites: PHYS 112, 213, and 214, or equivalent background in electricity and magnetism and mechanics; and permission of instructor. Intended for seniors and graduate students. D. A. Hammer.
For description, see ECE 484.

NS&E 545(5450) Energy Seminar (also ECE 587[5870], M&AE 545[5450])
Fall, spring. 1 credit; may be taken for credit both semesters. D. A. Hammer.
For description, see ECE 587.

NS&E 590(5900) Independent Study
Fall, spring. 1–4 credits. Letter or S-U grades. Staff.
Independent study or project under guidance of a faculty member.

NS&E 591(5910) Project
Fall, spring. 1–6 credits. Staff.
Master of engineering or other project under guidance of a faculty member.

NS&E 413(4130) Introduction to Nuclear Science and Engineering (also ECE/M&AE/T&AM 413[4130])
Fall. 3 credits. Prerequisites: PHYS 214 and MATH 294.
For description, see T&AM 413.

OPERATIONS RESEARCH AND INFORMATION ENGINEERING

T. Apanasovich, L. J. Billera, R. G. Bland, J. R. Callister, M. J. Eisner, E. Friedman, X. Guo, S. Henderson, P. L. Jackson, R. A. Jarrow, A. Lewis, M. Lewis, W. L. Maxwell, J. A. Muckstadt, N. Prabhu, P. Protter, J. Renegar, S. I. Resnick, R. Roundy, D. Ruppert, P. Rusmevichientong, G. Samorodnitsky, A. Schied, D. Shmoys, E. Tardos, M. J. Todd, H. Topaloglu, L. E. Trotter, Jr., B. W. Turnbull, S. Weber, D. P. Williamson

OR&IE 311(3800) Information Systems and Analysis
Spring. 4 credits.
A systematic and hierarchical approach to the development of information systems, featuring business case justification, requirements analysis, use case analysis, functional analysis, structural design, object-oriented modeling, database design, verification and validation, and project schedule estimation. Graphical tools of analysis (e.g., the Unified Modeling Language) are emphasized. Examples are drawn from business and industrial processes. An integrative design project resulting in a detailed information system design specification (but not necessarily implementation) is required.

OR&IE 312(3120) Industrial Data and Systems Analysis
Spring. 4 credits. Prerequisite: ENGRD 270.
Database and statistical techniques for data mining, graphical display, and predictive analysis in the context of industrial systems (manufacturing and distribution). Database techniques include structured query language (SQL), procedural event-based programming (Visual Basic), and geographical information systems. Statistical techniques include multiple linear regression, classification, logistic regression, and time series forecasting. Industrial systems analysis includes factory scheduling and simulation, materials planning, cost estimation, inventory planning, and quality engineering.

OR&IE 320(3300) Optimization I
Fall. 4 credits. Prerequisite: MATH 221 or 294.
Formulation of linear programming problems and solutions by the simplex method. Related topics such as sensitivity analysis, duality, and network programming. Applications include such models as resource allocation and production planning. Introduction to interior-point methods for linear programming.

OR&IE 321(3310) Optimization II
Spring. 4 credits. Prerequisite: OR&IE 320 or equivalent.
A variety of optimization methods stressing extensions of linear programming and its applications but also including topics drawn from integer programming, dynamic programming, and network optimization. Formulation and modeling are stressed as well as numerous applications.

OR&IE 350(3150) Financial and Managerial Accounting
Fall and spring. 4 credits.
Covers principles of accounting, financial reports, financial-transactions analysis, financial-statement analysis, budgeting, job-order and process-cost systems, standard costing and variance analysis, and economic analysis of short-term decisions.

OR&IE 360(3500) Engineering Probability and Statistics II
Fall. 4 credits. Prerequisite: ENGRD 270 or equivalent.
A rigorous foundation in theory combined with the methods for modeling, analyzing, and controlling randomness in engineering problems. Probabilistic ideas are used to construct models for engineering problems, and statistical methods are used to test and estimate parameters for these models. Specific topics include random variables, probability distributions, density functions, expectation and variance, multidimensional random variables, and important distributions including normal, Poisson, exponential, hypothesis testing, confidence intervals, and point estimation using maximum likelihood and the method of moments.

OR&IE 361(3510) Introductory Engineering Stochastic Processes I
Spring. 4 credits. Prerequisite: OR&IE 360 or equivalent.
Uses basic concepts and techniques of random processes to construct models for a variety of problems of practical interest. Topics include the Poisson process, Markov chains, renewal theory, models for queuing, and reliability.

OR&IE 416(4100) Design of Manufacturing Systems
Fall. 4 credits. Prerequisite: senior OR&IE students or permission of instructor.
Project course in which students, working in teams, design a manufacturing logistics system and conduct capacity, material flow, and cost analysis of their design. Meetings between project teams and faculty advisors are substituted for some lectures. Analytical methods for controlling inventories, planning production, and evaluating system performance are presented in lectures.

[OR&IE 431(4330) Discrete Models
Fall. 4 credits. Prerequisites: OR&IE 320 and CS 211 or permission of instructor. Next offered 2009–2010.
Covers basic concepts of graphs, networks, and discrete optimization. Fundamental models and applications, and algorithmic techniques for their analysis. Specific optimization models studied include flows in networks, the traveling salesman problem, and network design.]

OR&IE 432(4320) Nonlinear Optimization
Fall. 4 credits. Prerequisite: OR&IE 320.
Introduction to the practical and theoretical aspects of nonlinear optimization. Gives attention to the computational efficiency of algorithms and the application of nonlinear techniques to linear programming; e.g., interior-point methods. Introduces methods of numerical linear algebra as needed.

[OR&IE 434(4300) Optimization Modeling
Spring. 3 credits. Prerequisite: at least B– in OR&IE 321/521. Next offered 2009–2010.
Emphasizes modeling complicated decision problems as linear programs, integer programs, or highly structured nonlinear programs. Besides modeling, students are required to assimilate articles from the professional literature and to master relevant software.]

[OR&IE 435(4350) Introduction to Game Theory
Fall. 4 credits. Next offered 2008–2009.
Broad survey of the mathematical theory of games, including such topics as two-person matrix and bimatrix games; cooperative and noncooperative n-person games; and games in extensive, normal, and characteristic function form. Economic market games. Applications to weighted voting and cost allocation.]

[OR&IE 436(4360) A Mathematical Examination of Fair Representation
Spring. 3 credits. Prerequisite: MATH 222 or 294 or permission of instructor. Next offered 2009–2010.
Covers the mathematical aspects of the political problem of fair apportionment. The most recognizable form (in the United States) of apportionment is the determination of the number of seats in the U.S. House of Representatives awarded to each state. The constitution indicates that the apportionment should reflect the relative populations, but it does not prescribe a specific method. Indivisibility of seats leads us to interesting mathematical questions and a long, rich, and fractious political history involving many famous figures. The basic ideas extend beyond apportionment of legislatures (in both federal systems and proportional representation systems) to other realms where

indivisible resources are to be allocated among competing constituencies.]

OR&IE 437(4370) Computational Optimization

Spring. 4 credits. Prerequisite: OR&IE 320. Corequisite: OR&IE 321.

Covers computational implementation and related methodology for solving large-scale, real-world integer programming problems. Primary emphasis is on branch-and-cut technology: pre-processing, cut strength, exact and heuristic separation techniques, branching strategies, multi-processing. Hands-on experience with state-of-the-art software for various discrete optimization models, including the traveling salesman, capacitated vehicle routing, and air crew scheduling models; experimentation with massively parallel computational implementation on the IBM BlueGene computer for the largest feasible subsystem problem.

OR&IE 451(4150) Economic Analysis of Engineering Systems

Spring. 4 credits. Prerequisites: OR&IE 320 and 350.

Topics include financial planning, including cash-flow analysis and inventory flow models; engineering economic analysis, including discounted cash flows and taxation effects; application of optimization techniques, as in equipment replacement or capacity expansion models, and issues in designing manufacturing systems. Includes a student group project.

OR&IE 452(4152) Entrepreneurship for Engineers (also M&AE/ENGRG 461[4610])

Fall. 3 credits. Prerequisite: upper-class engineers or permission of instructor.

For description see M&AE 461.

[OR&IE 453(4154) Revenue Management

Fall. 3 credits. Prerequisites: OR&IE 320 and 360, or permission of instructor. Next offered 2008–2009.

Covers revenue management concepts, models used in practice, and possible extensions; forecasting techniques, including time series methods, booking curves, and customer preference models; demand uncensoring; overbooking and optimization with emphasis on stochastic models of demand, benefit measurement; computational and technological issues; bid-prices and dynamic programming techniques; examples from the airlines, hotels, car-rental agencies, restaurants, and other industries.]

[OR&IE 462(4520) Introductory Engineering Stochastic Processes II

Spring. 4 credits. Prerequisite: OR&IE 361 or equivalent. Next offered 2009–2010.

Topics include stationary processes, martingales, random walks, and gambler's ruin problems, processes with stationary independent increments, Brownian motion and other cases, branching processes, renewal and Markov-renewal processes, reliability theory, Markov decision processes, optimal stopping, statistical inference from stochastic models, and stochastic comparison methods for probability models. Applications to population growth, spread of epidemics, and other models.]

[OR&IE 464(4540) Extreme Value Analysis with Applications to Finance and Data Communications

Spring. 3 credits. Prerequisites: undergraduate and M.Eng. students; stochastic processes course at level of OR&IE 361; statistics course. Next offered 2009–2010.

Covers the basic models of extreme events used in hydrology, finance, insurance, environmental science (pollution controls), reliability, risk management. The course material intersects the related field of heavy tailed modeling and the implications of heavy tails in insurance and data networks.]

OR&IE 468(4600) Introduction to Financial Engineering

Fall. 3 credits. Prerequisites: OR&IE 360 and 361.

This is an introduction to the most important notions and ideas in modern financial engineering, such as arbitrage, pricing, derivatives, options, interest rate models, risk measures, equivalent martingale measures, complete and incomplete markets, etc. Most of the time the course deals with discrete time models. This course can serve as a preparation for a course on continuous time financial models such as OR&IE 568.

OR&IE 473(4630) Operations Research Tools for Financial Engineering

Spring. 3 credits. Prerequisites: engineering math through MATH 294 and ENGRD 270 and OR&IE 360. No previous knowledge of finance required.

Introduction to the applications of OR techniques, e.g., probability, statistics, and optimization, to finance and financial engineering. First reviews probability and statistics and then surveys assets returns, ARIMA time series models, portfolio selection, regression, CAPM, option pricing, GARCH models, fixed-income securities, resampling techniques, and behavioral finance. Also covers the use of MATLAB, MINITAB, and SAS for computation.

OR&IE 474(4740) Statistical Data Mining I

Fall. 4 credits. Prerequisites: OR&IE 360 and MATH 294 or equivalent; or permission of instructor.

Examines the statistical aspects of data mining, the effective analysis of large data sets. The first half of the course covers the process of building and interpreting statistical models in a variety of settings including multiple regression and logistic regression. The second half connects these ideas to techniques being developed to handle the large data sets that are now routinely encountered in scientific and business applications. Assignments are done using one or more statistical computing packages.

OR&IE 476(4710) Applied Linear Statistical Models

Spring, weeks 1–7. 2 credits. Prerequisite: ENGRD 270.

Topics include multiple linear regression, diagnostics, model selection, inference, one and two factor analysis of variance. Theory and applications both treated. Use of MINITAB stressed.

OR&IE 480(4800) Information Technology

Spring. 4 credits. Pre- or corequisites: CS/ENGRD 211, plus either OR&IE 311 or 312.

This course covers a variety of fundamental aspects of information technology. Topics may include: information transmission, storage, encryption and security; the value of information and the economics of information goods; databases, the Internet, World Wide Web, wireless and cellular networks, and peer-to-peer networks.

[OR&IE 481(4810) Delivering OR Solutions with Information Technology

Spring. 3 credits. Prerequisite: OR&IE 480. Next offered 2008–2009.

Study of ways information technology is used to deliver operations research methodology in real applications, including decision support systems, embedded operations research techniques, packaged software, and web-based techniques. Several actual applications are investigated. Labs introduce Visual Basic for Applications (VBA) for decision support.]

[OR&IE 483(4850) Applications of Operations Research and Game Theory to Information Technology

Spring. 3 credits. Prerequisites: OR&IE 321, 361, or permission of instructor. Next offered 2009–2010. Covers a variety of operations research and game theoretic problems arising in information technology. Examples include web searching, network routing and congestion control, online auctions, and trust and reputations in electronic interactions.]

OR&IE 490(4990) Teaching in OR&IE

Fall, spring. Variable credit. Prerequisite: permission of instructor.

Involves working as a TA in an OR&IE course. The instructor assigns credits (the guideline is 1 credit per four hours per week of work with a limit of 3 credits).

OR&IE 499(4999) OR&IE Project

Fall, spring. Variable credit. Prerequisite: permission of instructor.

Project-type work, under faculty supervision, on a real problem existing in some firm or institution. Opportunities in the course may be discussed with the associate director.

OR&IE 512(5140) Applied Systems Engineering (also CEE/CIS 504[5040], ECE 512[5120], M&AE 591[5910])

Fall. 3 credits. Prerequisite: permission of instructor.

For description, see SYSEN 510.

OR&IE 513(5142) Systems Analysis Architecture, Behavior, and Optimization (also CEE/CIS 505[5050], ECE 513[5130], M&AE 592[5920])

Spring. 3 credits. Prerequisite: CEE/CIS 504, ECE/OR&IE 512, or M&AE 592.

For description, see SYSEN 520.

OR&IE 515(5100) Design of Manufacturing Systems

Fall. 4 credits. Prerequisite: graduate students in engineering and business school; permission of instructor.

For description, see OR&IE 416.

OR&IE 516(5110) Case Studies

Fall. 1 credit. Prerequisite: M.Eng. students in OR&IE.

Presents students with an unstructured problem that resembles a real-world situation. Students work in project groups to formulate mathematical models, perform computer analyses of the data and models, and present oral and written reports.

OR&IE 518(5126) Supply Chain Management

Spring. 3 credits. Prerequisites: one of the following: OR&IE 312, 416, or 562.

A supply chain is the scope of activities that convert raw materials (e.g., wheat) to finished products delivered to the end consumer (e.g., a box of cereal at the local P&C), usually spanning several corporations. Supply chain management focuses on the flow of products, information, and money through the supply chain. An overview of issues, opportunities, tools, and approaches. Emphasis is on business processes, system dynamics, control, design, re-engineering. Covers the relationship between the supply chain and the company's strategic position relative to its clients and its competition. Considers dimensions of inter-corporate relationships with partners, including decision-making, incentives, and risk.

[OR&IE 519(5130) Service System Modeling and Design

Spring. 3 credits. Prerequisites: OR&IE 321, 361; ability to program simple algorithms in some appropriate environment (e.g., VisualBasic or MATLAB). Recommended: OR&IE 580 and OR&IE 581. Next offered 2009–2010.

Today's economy is dominated by service industries. These systems differ from manufacturing industries in many ways, but primarily in the level of interaction with the customer. Examples of service systems include contact centers (aka call centers), airlines, and hospitals. This course covers various techniques that are useful in the analysis and design of such systems. It is structured around a number of cases that drive the need for the theory. The emphasis is on modeling and solving the models. Both operational and strategic decisions are covered through appropriate examples.]

OR&IE 520(5300) Operations Research I: Optimization I

For description, see OR&IE 320.

OR&IE 521(5310) Optimization II

For description, see OR&IE 321.

OR&IE 522(5311) Operations Research I: Topics in Linear Optimization

Spring. 1 credit. Pre- or corequisite: M.Eng. students in OR&IE; OR&IE 520. Not open to students who have already taken OR&IE 321 or 521.

Extension of OR&IE 520 that deals with applications and methodologies of dynamic programming, integer programming, and large-scale linear programming.

OR&IE 523(5510) Operations Research II: Introduction to Stochastic Processes I

For description, see OR&IE 361.

[OR&IE 525(5120) Production Planning and Scheduling Theory and Practice

Fall. 4 credits. Corequisites: OR&IE 320, 360. Next offered 2009–2010.

Topics include production planning, including MRP, linear programming, and related concepts. Scheduling and sequencing work in manufacturing systems. Job release strategies and control of work in process inventories. Focus is on setup time as a determinant of plans and schedules.]

OR&IE 528–529(5190–5191) Selected Topics in Applied Operations Research

Fall, spring. Variable credit. Prerequisite: permission of instructor.

Current topics dealing with applications of operations research.

OR&IE 533(5340) Heuristic Methods for Optimization (also CEE 509[5090], CIS 572[5720])

Fall. 3 or 4 credits. Prerequisite: graduate standing or CS/ENGRD 211, 321 or CEE/ENGRD 320 or permission of instructors.

For description, see CEE 509.

OR&IE 551(5150) Economic Analysis of Engineering Systems

Spring. 4 credits. Prerequisites: OR&IE 320 and 350. Lectures concurrent with OR&IE 451.

For description, see OR&IE 451.

OR&IE 558(5660) Valuation of Interest Rate Securities in Practice

Fall. 3 credits. Prerequisite: OR&IE 360.

Provides a bridge between mathematical finance theory and practical applications. Considers various interest rate financial instruments, with particular emphasis on Mortgage Backed Securities. Develops real market-techniques for pricing, trading, and assessing relative value. Explores how specific interest rate and volatility views can be expressed and/or leveraged via trading strategies.

[OR&IE 559(5630) Computational Methods in Finance

Spring. 3 credits. Prerequisite: OR&IE M.Eng. students. Next offered 2008–2009.

This course covers computational techniques such as binomial trees, solution of PDEs, and Monte Carlo simulation for pricing financial instruments such as European and American options, path-dependent options, and bonds. Other computational topics such as delta and gamma hedging, Value at Risk, and portfolio problems will also be covered. The emphasis will be on implementation.]

OR&IE 560(5500) Engineering Probability and Statistics II

For description, see OR&IE 360.

[OR&IE 561(5560) Queueing Systems: Theory and Applications

Fall. 3 credits. Prerequisite: OR&IE 361 or permission of instructor. Next offered 2009–2010.

Covers basic queueing models; delay and loss systems; finite source, finite capacity, balking, reneging; systems in series and in parallel; FCFS versus LCFS; busy period problems; output; design and control problems; priority systems; queueing networks; the product formula; time sharing; server vacations; and applications to equipment maintenance, computer operations and flexible manufacturing systems.]

OR&IE 562(5122) Inventory Management

Fall. 3 credits. Prerequisite: OR&IE 321, 361, or permission of instructor.

The first portion of this course is devoted to the analysis of several deterministic and probabilistic models for the control of single and multiple items at one of many locations. The second portion is presented in an experiential learning format. The focus is on analyzing and designing an integrated production and distribution system for a global company. Applications are stressed throughout.

OR&IE 563(5550) Applied Time-Series Analysis

Fall. 3 credits. Prerequisites: OR&IE 361 and ENGRD 270 or permission of instructor.

The first part of this course treats regression methods to model seasonal and nonseasonal data. After that, Box-Jenkins models, which are versatile, widely used, and applicable to nonstationary and seasonal time series, are covered in detail. The various stages of model identification, estimation, diagnostic checking, and forecasting are treated. Analysis of real data is carried out. Assignments require computer work with a time-series package.

[OR&IE 564(5520) Introductory Engineering Stochastic Processes II

Spring. 4 credits. Prerequisite: OR&IE 361 or equivalent.

Lectures concurrent with OR&IE 462. For description, see OR&IE 462.]

OR&IE 565(5960) Applied Financial Engineering

Spring. 5 credits. Project satisfies M.Eng. project requirement. Prerequisite: M.Eng. students.

This course has two components: a sequence of lectures and a project. The lectures are given by the faculty for the course and by invited speakers from the financial industry.

[OR&IE 566(5540) Extreme Value Analysis with Applications to Finance and Data Communications

Spring. 3 credits.

For description, see OR&IE 464.]

[OR&IE 567(5620) Credit Risk: Modeling, Valuation, and Management

Spring. 4 credits. Prerequisite: OR&IE 361. Next offered 2008–2009.

Credit risk refers to losses due to changes in the credit quality of a counter party in a financial contract. This course is an introduction to the modeling and valuation of credit risks. Emphasis is on credit derivative instruments used for hedging credit risks, including credit swaps, spread options, and collateralized debt obligations.]

OR&IE 568(5600) Financial Engineering with Stochastic Calculus I

Fall. 4 credits. Prerequisite: knowledge of probability at level of OR&IE 360.

Introduction to continuous-time models of financial engineering and the mathematical tools required to use them, starting with the Black-Scholes model. Driven by the problem of derivative security pricing and hedging in this model, the course develops a practical knowledge of stochastic calculus from an elementary standpoint, covering topics including Brownian motion, martingales, the Ito formula, the Feynman-Kac formula, and Girsanov transformations.

OR&IE 569(5610) Financial Engineering with Stochastic Calculus II

Spring. 4 credits. Prerequisite: OR&IE 568.

Building on the foundation established in OR&IE 568, this course presents no-arbitrage theories of complete markets, including models for equities, foreign exchange, and fixed-income securities, in relation to the main problems of financial engineering: pricing and hedging of derivative securities, portfolio optimization, and risk management. Other topics include model calibration and incomplete markets.

OR&IE 573(5640) Statistics for Financial Engineering

Spring. 4 credits. Pre- or corequisite: OR&IE 569.

Times series, GARCH, and stochastic volatility models. Calibration of financial engineering models. Estimation of diffusion models. Data mining in financial engineering. Estimation of risk measures. Bayesian statistics. Students will be instructed in the use of MATLAB and R software; prior knowledge of MATLAB is helpful but not required. This course is intended for M.Eng. students in financial engineering and assumes some familiarity with finance and financial engineering. Students not in the M.Eng. program are welcome if they have a suitable background. Students with no background in finance should consider taking OR&IE 473 instead.

OR&IE 575(4711) Experimental Design

Spring; weeks 8–14 (alternates with 576). 2 credits. Prerequisite: OR&IE 476.

Covers randomization, blocking, sample size determination, factorial designs, 2^p full and fractional factorials, response surfaces, Latin squares, split plots, and Taguchi designs. Engineering applications. Computing in MINITAB or SAS.

[OR&IE 576(4712) Regression

Spring; weeks 8–14 (alternates with 575). 2 credits. Prerequisite: OR&IE 476. Next offered 2009–2010.

Covers nonlinear regression, advanced diagnostics for multiple linear regression, collinearity, ridge regression, logistic regression, nonparametric estimation including spline and kernel methods, and regression with correlated errors. Computing in MINITAB or SAS.]

[OR&IE 577(5770) Quality Control

Fall. 3 credits. Prerequisite: ENGRD 270. Next offered 2009–2010.

Covers concepts and methods for process and acceptance control; control charts for variables and attributes; process capability analysis; acceptance sampling; continuous sampling plans; life tests; and use of experimental design and Taguchi methods for off-line control.]

[OR&IE 579(5650) Quantitative Methods of Financial Risk Management

Fall. 3 credits. Prerequisite: OR&IE 360. Next offered 2008–2009.

A historical perspective of market risk measurement including the Markowitz, CAPM and APT models, a description of the value-at-risk approach and an overview of VaR variants and extensions such as delta-VaR, CVaR etc. The course will survey other methods for evaluating risk and consider multivariate methods for evaluating portfolios requiring copula tools which have become popular. Topics in credit risk: methods for determining default probabilities and company ratings based on financial ratios (logit, probit and discriminant analysis, decision trees, etc.), and approaches to measuring credit risk which can be roughly divided into structural models and reduced-form models.]

OR&IE 580(4580) Monte Carlo Simulation

Fall, weeks 1–7. 2 credits. Prerequisite: OR&IE 360 (may be taken concurrently) and computing experience, or permission of instructor.

Introduction to Monte Carlo simulation. Emphasizes tools and techniques needed in practice. Random variate, vector, and process generation, input and output analysis, modeling.

OR&IE 581(4581) Discrete-Event Simulation

Fall; weeks 8–14. 2 credits. Prerequisite: OR&IE 580.

Introduction to discrete-event simulation. Emphasis on tolls and techniques needed in practice. Modeling using a discrete-event simulation language, output analysis.

OR&IE 582(4582) Monte Carlo Methods in Financial Engineering

Fall; weeks 8–14. 2 credits. Prerequisite: OR&IE 580.

An overview of Monte Carlo methods as they apply in financial engineering. Generating sample paths. Variance reduction (including quasi random number), discretization, and sensitivities. Applications to derivative pricing and risk management.

OR&IE 597(5940) Systems Engineering Project

Fall; R grade only; spring, 8 credits. Prerequisite: M.Eng. students enrolled in systems engineering option.

Substantial, group-based design project that has a strong systems design component. The project must be approved by an ASE 1 instructor before the student enrolls in the course. (The following projects are pre-approved: FSAE, HEV, Robocup, Brain.) A formal report is required.

OR&IE 598(5910) Master of Engineering Manufacturing Project

Fall, R grade only; spring, 5 credits. Prerequisite: M.Eng. students enrolled in manufacturing option.

Project course coordinated by Center for Manufacturing Enterprise.

OR&IE 599(5980) Project

Fall, R grade only; spring, 5 credits. Prerequisite: M.Eng. students.

Identification, analysis, design, and evaluation of feasible solutions to some applied problem in the OR&IE field. A formal report and oral defense of the approach and solution are required.

[OR&IE 625(6335) Scheduling Theory

Fall. 3 credits. Next offered 2009–2010.

Scheduling and sequencing problems, including single-machine problems, parallel-machine scheduling, and shop scheduling. The emphasis is on the design and analysis of polynomial time optimization and approximation algorithms and on related complexity issues.]

[OR&IE 626(6122) Advanced Production and Inventory Planning

Spring. 4 credits. Next offered 2008–2009.

Introduction to a variety of production and inventory control planning problems, the development of mathematical models corresponding to these problems, and a study of approaches for finding solutions.]

[OR&IE 627(6127) Computational Issues in Large Scale Data-Driven Models

Fall. 3 credits. Pre- or corequisites: OR&IE 630, 650 and 670. Next offered 2009–2010.

Availability of massive datasets such as web logs and point-of-sale transactions raises new modeling and computational issues. This course provides an introduction to this emerging research area. Topics include data-driven models in operation management, asymptotic statistics, uniform convergence of empirical process, and efficient computational methods. There is discussion of applications in engineering, economics, and marketing, along with current open research problems.]

OR&IE 629(6350) Foundations of Game Theory and Mechanism Design for Engineering Applications

Fall. 3 credits. Prerequisite: basic knowledge of operations research at level of OR&IE 630 and 650. No prior knowledge of game theory or computer networks assumed.

Provides a rigorous foundation for the applications of game theory and mechanism design to problems in operations research and computer science. The goal is to develop a deep understanding of the fundamental issues that are important in many applications while presenting many current open research problems.

OR&IE 630(6300) Mathematical Programming I

Fall. 4 credits. Prerequisites: advanced calculus and elementary linear algebra.

Rigorous treatment of the theory and computational techniques of linear programming and its extensions, including formulation, duality theory, algorithms; sensitivity analysis; network flow problems and algorithms; theory of polyhedral convex sets, systems of linear equations and inequalities, Farkas' Lemma; and exploiting special structure in the simplex method and computational implementation.

[OR&IE 631(6310) Mathematical Programming II

Spring. 4 credits. Prerequisite: OR&IE 630. Next offered 2008–2009.

Continuation of OR&IE 630. Introduces nonlinear programming, interior-point methods for linear programming, complexity theory, and integer programming. Includes some discussion of dynamic programming and elementary polyhedral theory.]

[OR&IE 632(6320) Nonlinear Programming

Spring. 3 credits. Prerequisite: OR&IE 630. Next offered 2009–2010.

Necessary and sufficient conditions for unconstrained and constrained optima. Topics include the duality theory, computational methods for unconstrained problems (e.g., quasi-Newton algorithms), linearly constrained problems (e.g., active set methods), and nonlinearly constrained problems (e.g., successive quadratic programming, penalty, and barrier methods).]

OR&IE 633(6330) Graph Theory and Network Flows

Fall. 3 credits. Prerequisite: permission of instructor.

Topics include directed and undirected graphs; bipartite graphs; Hamilton cycles and Euler tours; connectedness, matching, and coloring; flows in capacity-constrained networks; and maximum flow and minimum cost flow problems.

[OR&IE 634(6334) Combinatorial Optimization

Fall. 3 credits. Next offered 2009–2010.

Topics in combinatorics, graphs, and networks, including matching, matroids, polyhedral combinatorics, and optimization algorithms.]

OR&IE 635(6325) Interior-Point Methods for Mathematical Programming

Fall. 3 credits. Prerequisites: MATH 411 and OR&IE 630, or permission of instructor.

Interior-point methods for linear, quadratic, and semidefinite programming and, more generally, for convex programming. Discusses the basic ingredients—barrier functions, central paths, and potential functions—that go into the construction of polynomial-time algorithms and various ways of combining them. Emphasizes recent mathematical theory and the most modern viewpoints.

[OR&IE 636(6336) Integer Programming
Fall. 3 credits. Prerequisite: OR&IE 630. Next offered 2009–2010.
Topics include discrete optimization; linear programming in which the variables must assume integral values; theory, algorithms, and applications; and cutting-plane and enumerative methods, with additional topics drawn from recent research in this area.]

OR&IE 637(6327) Semidefinite Programming
Spring. 3 credits. Pre- or corequisite: OR&IE 635.
Covers linear optimization over the cone of positive semidefinite symmetric matrices; applications to control theory, eigenvalue optimization, and strong relaxations of combinatorial optimization problems; duality; computational methods, particularly interior-point algorithms.

[OR&IE 639(6328) Convex Analysis
Spring. 3 credits. Prerequisite: OR&IE 630 or permission of instructor. Next offered 2009–2010.
Self-contained development of convex analysis and optimization. Convex sets and functions, subgradients, continuity, Fenchel, conic, and Lagrangian duality. Nonsmooth analysis: Clarke and limiting subgradients. Self-concordance and smooth convex optimization. Bundle methods for nonsmooth convex optimization.]

OR&IE 640(6570) Queues and Control of Queues: The Dynamic Programming Approach
Fall. 3 credits.
We will cover basic queueing theory followed by an introduction to Markov decision processes (MDPs). The second part of the class will cover the use of MDPs to develop control policies in a variety of queueing settings.

OR&IE 650(6500) Applied Stochastic Processes
Fall. 4 credits. Prerequisite: one-semester calculus-based probability course.
Introduction to stochastic processes that presents the basic theory together with a variety of applications. Topics include Markov processes, renewal theory, random walks, branching processes, Brownian motion, stationary processes, martingales, and point processes.

OR&IE 651(6510) Probability
Spring. 4 credits. Prerequisite: real analysis at level of MATH 413; one-semester calculus-based probability course.
Covers sample spaces, events, sigma fields, probability measures, set induction, independence, random variables, expectation, review of important distributions and transformation techniques, convergence concepts, laws of large numbers and asymptotic normality, and conditioning.

OR&IE 662(6540) Advanced Stochastic Processes
Fall. 3 credits. Prerequisite: OR&IE 651 or equivalent.
Topics include Brownian motion, martingales, Markov processes, and topics selected from: diffusions, stationary processes, point processes, weak convergence for stochastic processes and applications to diffusion approximations, Lévy processes, regenerative phenomena, random walks, and stochastic integrals.

OR&IE 670(6700) Statistical Principles
Fall. 4 credits. Corequisite: OR&IE 650 or equivalent.
Topics include review of distribution theory of special interest in statistics: normal, chi-square, binomial, Poisson, t, and F; introduction to statistical decision theory; sufficient statistics; theory of minimum variance unbiased point estimation; maximum likelihood and Bayes estimation; basic principles of hypothesis testing, including Neyman-Pearson Lemma and likelihood ratio principle; confidence interval construction; and introduction to linear models.

[OR&IE 671(6710) Intermediate Applied Statistics
Spring. 3 credits. Prerequisite: OR&IE 670 or equivalent. Next offered 2008–2009.
Topics include statistical inference based on the general linear model; least-squares estimators and their optimality properties; likelihood ratio tests and corresponding confidence regions; and simultaneous inference. Applications in regression analysis and ANOVA models. Covers variance components and mixed models. Use of the computer as a tool for statistics is stressed.]

[OR&IE 673(6630) Empirical and Computational Issues in Finance
Spring. 3 credits. Prerequisites: stochastic processes course at level of OR&IE 650; statistics course at level of OR&IE 670, or permission of instructor. Next offered 2008–2009.
Designed to introduce students to existing empirical work in finance and to demonstrate the use of statistical, econometric, and numerical methods in the analysis of financial data. Topics include linear and nonlinear time series analysis, high-frequency data and market microstructure, continuous-time models, extreme values and quantile estimation, volatility models, and MCMC methods. Numerous applications using market data are presented. MATLAB programming skills are useful.]

OR&IE 674(6740) Statistical Learning Theory for Data Mining
Fall. 3 credits. Prerequisites: probability course at level of OR&IE 651; statistics course at level of OR&IE 670.
Provides a thorough grounding in probabilistic and computational methods for statistical data mining. Covers a subset of the following topics from supervised and unsupervised data mining: the framework of learning. Performance measures and model selection. Methodology, theoretical properties and computing algorithms used in parametric and nonparametric methods for regression and classification. Frequentist and Bayesian methods.

OR&IE 677(6720) Sequential Methods in Statistics
Spring. 3 credits. S-U grades only.
The statistical theory of sequential design and analysis of experiments has many applications; including monitoring data from clinical trials in medical studies and quality control in manufacturing operations. This course covers classical sequential hypothesis tests, Wald's SPRT, stopping rules, Kiefer-Weiss test, optimality, group sequential methods, estimation, repeated confidence intervals, stochastic curtailment, adaptive designs, and Bayesian and decision theoretic approaches.

[OR&IE 678(6780) Bayesian Statistics and Data Analysis
Spring. 3 credits. Prerequisites: OR&IE 670 and some knowledge of measure theoretic probability (e.g., co-registration in OR&IE 650). Next offered 2009–2010.
Priors, posteriors, Bayes estimators, Bayes factors, credible regions, hierarchical models, computational methods (especially MCMC), empirical Bayes methods, Bayesian robustness. Includes data analysis and MCMC computation in WinBUGS and possibly other languages such as MATLAB.]

OR&IE 680(6580) Simulation
Spring. 4 credits. Prerequisite: computing experience and OR&IE 650 or equivalent, or permission of instructor.
Introduction to Monte Carlo and discrete-event simulation. Emphasizes underlying theory. Random variate generation, input and output analysis, variance reduction, selection of current research topics.

OR&IE 728–729(7190–7191) Selected Topics in Applied Operations Research
Fall, spring. Credit TBA.
Current research topics dealing with applications of operations research.

OR&IE 738–739(7390–7391) Selected Topics in Mathematical Programming
Fall, spring. Credit TBA.
Current research topics in mathematical programming.

OR&IE 768–769(7590–7591) Selected Topics in Applied Probability
Fall, spring. Credit TBA.
Topics are chosen from current literature and research areas of the staff.

OR&IE 778–779(7790–7791) Selected Topics in Applied Statistics
Fall, spring. Credit TBA.
Topics are chosen from current literature and research of the staff.

OR&IE 790(7900) Special Investigations
Fall, spring. Credit TBA.
For individuals or small groups. Study of special topics or problems.

OR&IE 799(9999) Thesis Research
Fall, spring. Credit TBA.
For individuals doing thesis research for master's or doctoral degrees.

OR&IE 891(9000) Operations Research Graduate Colloquium
Fall, spring. 1 credit.
Weekly one and one-half hour meeting devoted to presentations by distinguished visitors, by faculty members, and by advanced graduate students on topics of current research in the field of operations research.

OR&IE 893–894(9100–9101) Enterprise Engineering Colloquium (also M&AE 594[5940])
893, fall; 894, spring. 1 credit each semester. S-U grades.
Weekly meeting for master of engineering students. Discussion with industry speakers and faculty members on the uses of engineering in the economic design, manufacturing, marketing, and distribution and goods and services.

SYSTEMS ENGINEERING

P. L. Jackson, director; A. R. George, assoc. director; M. A. Turnquist, director of graduate studies; M. Campbell, R. D'Andrea, R. A. Davidson, E. Garcia, H. O. Gao, A. S. Lewis, J. A. Muckstadt, A. F. Myers, L. K. Nozick, M. Peck, R. O. Roundy, F. B. Schneider, B. Selman, C. A. Shoemaker, J. R. Stedinger, R. J. Thomas, H. Topaloglu, F. J. Wayne, Jr.

SYSEN 101(1010) Getting Design Right: A Systems Approach
Summer six-week session. 2 credits. Web-delivered. Instructor: Peter L. Jackson.
This course is a freshman-level exposure to the product design process. The process of getting design right is sometimes called systems engineering. We explain the process using the acronym DMEODVI (Define, Measure, Explore, Optimize, Design, Verify, and Iterate). The process begins with understanding customer requirements and ends with validating the design against those requirements. It can then be iterated to greater levels of design detail. The focus is not on detailed engineering design but rather on the process of ensuring that the detailed design will meet the needs of the customer. Students work through the steps of the process with reference to a particular product design challenge. The course is web-delivered using the Blackboard learning instruction system. Pre-requisites: high school mathematics and science, and familiarity with spreadsheet modeling (e.g., MS Excel).

SYSEN 510(5100) Applied Systems Engineering (also CEE/CS 504[5040], ECE/OR&IE 512[5120], M&AE 591[5910])
Fall. 3 credits. Prerequisites: senior or graduate standing in an engineering field; concurrent or recent (past two years) enrollment in group-based project with strong system design component approved by course instructor. M. Peck, A. R. George, and P. Jackson.
Fundamental ideas of systems engineering, and their application to design and development of various types of engineered systems. Defining system requirements, creating effective project teams, mathematical tools for system analysis and control, testing and evaluation, economic considerations, and the system life cycle. Students majoring in Systems Engineering enroll in SYSEN 510. Students taking the minor in Systems Engineering enroll in CEE/CIS 504, ECE/OR&IE 512, or M&AE 591. Students in Continuing Education enroll in SYSEN 511. Course is identical for all versions.

SYSEN 511(5110) Applied Systems Engineering
Fall. 3 credits. Intended for off-campus students. Prerequisites: senior or graduate standing in engineering field; concurrent or recent (past two years) enrollment in group-based project with strong system design component approved by course instructor. Staff.
For description, see SYSEN 510.

SYSEN 520(5200) Systems Architecture, Behavior, and Optimization (also M&AE 592[5920], CEE/CIS 505[5050], ECE 513[5130], OR&IE 513[5142])
Spring. 3 credits. Prerequisite: Applied System Engineering M&AE 591, CEE/CIS 504, ECE/OR&IE 512, SYSEN 510 or 511, or permission of instructor. H. Topaloglu.
This is an advanced course in the application of the systems engineering process to the architecture design and operation of complex systems. Topics include techniques for design, simulation, optimization, and control of complex systems. Case studies and system simulations in diverse areas provide context for the application of these techniques.

Students majoring in Systems Engineering enroll in SYSEN 520. Students taking the minor in Systems Engineering enroll in M&AE 592, CEE 505, CIS 505, ECE 513, or OR&IE 513. Students in Continuing Education enroll in SYSEN 521. Course is identical for all versions.

SYSEN 521(5210) Systems Architecture, Behavior, and Optimization
Spring. 3 credits. Intended for off-campus students. Prerequisites: Applied Systems Engineering or permission of instructor. Staff.
For description, see SYSEN 520.

SYSEN 530(5300) Systems Engineering for the Design and Operation of Reliable Systems (also M&AE 593[5930])
Fall. 3–4 credits. Prerequisites: SYSEN 510 and either OR&IE 270 or CEE 304 or permission of instructors. H. O. Gao.
Develops skills in the design, operation and control of systems for reliable performance. Focuses on four key themes; risk analysis (with a particular emphasis on risk assessment and risk characterization), modeling system reliability (including the development of statistical models based on accelerated life testing), quality control techniques and the optimization of system design for reliability. Students in Continuing Education enroll in SYSEN 531. Lectures are identical for all versions.

SYSEN 531(5310) Systems Engineering For the Design and Operation of Reliable Systems
Fall. 3–4 credits. Prerequisites: SYSEN 510 and either OR&IE 270 or CEE 304 or permission of instructor. H. O. Gao.
Intended for off-campus students. For description, see SYSEN 530.

SYSEN 570(5700) Special Topics in Systems Engineering
On demand. 1–4 credits. Staff.
Supervised study by individuals or small groups of one or more specialized topics not covered in regular courses.

SYSEN 571(5710) Practicum in Systems Engineering
On demand. 1–4 credits. Staff.
Supervised study by individuals or small groups of one or more specialized topics not covered in regular courses.

SYSEN 590(5900) Systems Engineering Design Project
1–8 credits. Prerequisite: permission of instructor. Staff.
A design project that incorporates the principles of systems engineering for a complex system. Projects are performed by teams of students working together to meet the requirements of the project.

SYSEN 680(6800) Topics in Systems Engineering Research
Spring. 1.5 credits. Staff.
Advanced topics in systems engineering research.

THEORETICAL AND APPLIED MECHANICS

T. J. Healey, chair; J. A. Burns, K. B. Cady, J. M. Guckenheimer, C. Y. Hui, J. T. Jenkins, S. Mukherjee, S. L. Phoenix, R. H. Rand, A. L. Ruina, W. H. Sachse, S. Strogatz, Z. J. Wang, A. Zehnder. Emeritus: H. D. Conway, E. Cranch, R. H. Lance.

Basics in Engineering Mathematics and Mechanics

[T&AM 118(1180) Design Integration: DVDs and iPods (also ENGRI 118[1180])
Spring. 3 credits. Next offered 2008–2009.
Course in Introduction to Engineering series. For description, see ENGRI 118.]

T&AM 202(2020) Mechanics of Solids (also ENGRD 202[2020])
Fall, spring. 4 credits Prerequisite: PHYS 112, co-registration in MATH 192, or permission of instructor.
For description, see ENGRD 202.

T&AM 203(2030) Dynamics (also ENGRD 203[2030])
Fall, spring. 3 credits. Prerequisite: T&AM 202, co-registration in MATH 293, or permission of instructor.
For description, see ENGRD 203.

Engineering Mathematics

T&AM 310(3100) Introduction to Applied Mathematics I
Fall, spring. 3 credits. Prerequisites: MATH/T&AM 293 and 294.
Covers initial value, boundary value, and eigenvalue problems in linear ordinary differential equations. Also covers special functions, linear partial differential equations. This is an introduction to probability and statistics. Use of computers to solve problems is emphasized.

[T&AM 311/511(3110/5110) Introduction to Applied Mathematics II
Spring. 3 credits. Prerequisite: MATH/T&AM 294 or equivalent (T&AM 311 can be taken independently of T&AM 310). Next offered 2008–2009.
Introduction to complex variable theory, including Cauchys integral theorem, Method of Residues, conformal mapping. Applications to inversion of transforms.]

[T&AM 312/512(3120/5120) Introduction to Mathematical Modeling
Spring. 3 credits. Prerequisite: MATH/T&AM 294 or equivalent (T&AM 311 can be taken independently of 310). Next offered 2008–2009.

Mathematical modeling of physical and biological systems.]

T&AM 610(6100) Methods of Applied Mathematics I

Fall. 3 credits. Intended for beginning graduate students in engineering and science. Intensive course requiring more time than normally available to undergraduates (see T&AM 310–311) but open to exceptional undergraduates by permission of instructor.

Emphasis is on applications. Course covers linear algebra, calculus of several variables, vector analysis, series, ordinary differential equations, and complex variables.

T&AM 611(6110) Methods of Applied Mathematics II

Spring. 3 credits. Prerequisite: T&AM 610 or equivalent.

Emphasis is on applications. Course covers partial differential equations, transform techniques, tensor analysis, and calculus of variations.

[T&AM 612(6120) Methods of Applied Mathematics III

Spring. 3 credits. Prerequisite: T&AM 610 and 611 or equivalent. Next offered 2008–2009.

Course topics include: integral transform, methods, Wiener-Hopf technique, solutions of integral equations and partial differential equations.]

[T&AM 613(6130) Asymptotics and Perturbation Methods

Spring. 3 credits. Prerequisites: T&AM 610 and 611 or equivalent. Next offered 2008–2009.

Topics include asymptotic behavior of solutions of linear and nonlinear and ODE symptotic expansion of integrals.]

[T&AM 617(6170) Advanced Mathematical Modeling—Biological and Fluid Dynamics

Spring. 3 credits. Next offered 2008–2009.

Covers the fundamentals of fluid dynamics that rises in biological fluid dynamics such as the motion of the microscopic cells in low Reynolds number flows and unsteady aerodynamics of flapping flight and free falling objects.]

[T&AM 718(7180) Topics in Applied Mathematics

Spring. 3 credits. Next offered 2009–2010.]

Continuum Mechanics

T&AM 455(4550) Introduction to Composite Materials (also CEE 477[4770], M&AE 455[4550], MS&E 555[5550])

Fall. 3 credits. Prerequisite: ENGRD 202.

Topics include introduction to composite materials; varieties and properties of fiber reinforcements and matrix materials; micromechanics of stiffness and stress transfer in discontinuous fiber/matrix arrays; orthotropic elasticity as applied to parallel fibers in a matrix and lamina; theory of stiffness (tension, bending, torsion) and failure of laminates and composite plates, including computer software for design; and manufacturing methods and applications for composites. There is a group component design and manufacturing paper required, and a group laboratory on laminated component fabrication.

T&AM 591(5910) Master of Engineering Design Project I

Fall. 3–12 credits, variable.

M.Eng. (mechanics) project related to the master of engineering in mechanics.

T&AM 592(5920) Master of Engineering Design Project I

Spring. 3–12 credits, variable.

M.Eng. (mechanics) project related to the master of engineering in mechanics.

T&AM 655(6550) Advanced Composite Materials (also CEE 676[6760], M&AE/MS&E 655[6550])

Spring. 4 credits. T&AM 455/555 not a prerequisite but excellent background.

Topics center around micromechanical and statistical (reliability) aspects of the strength and fatigue of fibrous composites. Topics include Hedgepeth shear-lag models of stress transfer around arrays of fiber breaks; statistical theories of composite failure to forecast reliability; stress distributions around holes and cuts in composite laminates; and compressive strength of composites.

T&AM 663(6630) Solid Mechanics I

Fall. 4 credits.

Rigorous introduction to solid mechanics emphasizing linear elasticity: tensors; deformations, rotations and strains; balance principles; stress; small-strain theory; linear elasticity, anisotropic and isotropic; basic theorems of elastostatics; and boundary-value problems, e. g., plates, St. Venant's solutions.

T&AM 664(6640) Solid Mechanics II

Spring. 4 credits. Prerequisites: MATH 610 and T&AM 663 or equivalent.

Preparation for advanced courses in solid mechanics. Topics include singular solutions in linear elasticity; plane stress, plane strain, anti-plane shear, airy stress functions; linear viscoelasticity; cracks and dislocations; classical plasticity; thermoelasticity; and three-dimensional elasticity.

[T&AM 751(7510) Continuum Mechanics and Thermodynamics

Spring. 3 credits. Prerequisites: T&AM 610 and 611; and 663 and 664 or equivalents. Next offered 2009–2010.

Course topics include kinematics; conservation laws; the entropy inequality; constitutive relations: frame indifference, material symmetry; and finite elasticity, rate-dependent materials, and materials with internal state variables.]

T&AM 752(7520) Nonlinear Elasticity

Spring. 3 credits. Prerequisites: T&AM 610, 611, and 751 or equivalents.

Review of governing equations. Topics include linearization and stability; constitutive inequalities; exact solution of special problems.

T&AM 753(7530) Fracture

Spring. 3 credits. Prerequisites: T&AM 610 or 611; and 663 and 664 or equivalents.

Also covers nonlinear rate-independent, small-scale deformation fracture mechanics: plastic fracture, J-integral, small-scale yielding, fields for stationary and growing cracks; failure mechanisms of polymers, ceramics, composites, and metals; void growth, load transfer between fibers, crazing; fracture testing; fatigue testing; computation of stress intensity factors; and plate theory and fracture.

[T&AM 754(7540) Topics in Continuum Mechanics]

[T&AM 757(7570) Inelasticity

Spring. 3 credits. Next offered 2009–2010.

Plasticity: general equations governing yielding, flow and work hardening. Linear viscoelasticity: simple rheological models; correspondence principle; hereditary integral approach.]

[T&AM 759(7590) Boundary Element Methods

Spring. 4 credits. Next offered 2009–2010.

Topics include a variety of applications of the boundary element method. Examples are: potential theory, linear elasticity, elasto-plasticity, micro and nano-electro-mechanical systems, meshfree boundary methods.]

Dynamics and Space Mechanics

T&AM 570(5700) Intermediate Dynamics

Fall. 3 credits.

Topics include Newtonian mechanics; motion in rotating coordinate systems; introduction to analytical mechanics; virtual work. Lagrangian mechanics; Hamilton's principle; small vibration and stability theory. Newtonian-Eulerian mechanics of rigid bodies; and gyroscopes. As time allows, introduction to orbital mechanics and chaos may be offered.

T&AM 578(5780) Nonlinear Dynamics and Chaos

Spring. 3 credits. Prerequisite: MATH/T&AM 293 or equivalent.

Introduction to nonlinear dynamics, with applications to physics, engineering, biology, and chemistry. Emphasizes analytical methods, concrete examples, and geometric thinking. Topics include one-dimensional systems; bifurcations; phase plane; nonlinear oscillators; and Lorenz equations, chaos, strange attractors, fractals, iterated mappings, period doubling, renormalization.

[T&AM 671(6710) Hamiltonian Dynamics

Spring. 3 credits. Prerequisite: T&AM 570 or equivalent. Next offered 2008–2009.

Course topics include review of Lagrangian mechanics, Kanes equations, Hamiltons principle, Hamiltons, canonical equations, Lie transforms, Hamilton-Jacobi theory; KAM theory; and Melnikovs method.]

[T&AM 672(6720) Celestial Mechanics (also ASTRO 579[6579])

Spring. 3 credits. Next offered 2008–2009.

Course topics include description of orbits; Hill curves, libration points; osculating orbital elements perturbation equations; effects of forces on satellite orbits; mechanics of planetary rings.]

[T&AM 673(6730) Mechanics of the Solar System (also ASTRO 571[6570])

Spring. 3 credits. Prerequisite: advanced undergraduate course in dynamics. Next offered 2008–2009.

Course topics include gravitational potentials, planetary gravity fields; free and forced rotations; Chandler wobble, polar wander, and damping of nutation.]

T&AM 675(6750) Nonlinear Vibrations

Fall. 3 credits. Prerequisite: T&AM 578 or equivalent.

Dynamics of nonlinear oscillators, including free and forced vibrations of both conservative and limit cycle oscillators, parametric excitation, systems of two, and N-coupled oscillators. Mathematical techniques include perturbation methods, center manifold reduction, and differential-delay equations.

[T&AM 768(7680) Elastic Waves in Solids
Fall. 3 credits.]

T&AM 776(7760) Applied Dynamical Systems (also MATH 717[7170])
Spring. 4 credits.
For description, see MATH 717.

[T&AM 796(7609) Mechanics of Terrestrial Locomotion
Spring. 3 credits. Prerequisite: T&AM 570, M&AE 571, or A+ level understanding of any sophomore or above mechanics course. Next offered 2008–2009.
The energetics and stability of people, other legged animals and robots are studied by mechanical analysis of simple models.]

Special Courses, Projects, and Thesis Research

T&AM 413(4130) Introduction to Nuclear Science and Engineering (also ECE 413[4130], A&EP 413[4130], NS&E 413, M&AE 458[4580])
Fall. 3 credits. Prerequisites: PHYS 214 and MATH 294.
Designed for juniors or seniors in any engineering field who want to prepare for graduate-level nuclear science and engineering courses at Cornell or elsewhere. Also can serve as a basic course for those who do not intend to continue in the field. Introduces the fundamentals of nuclear reactors. Topics include an overview of the field of nuclear engineering; nuclear structure, radioactivity, and reactions; interaction of radiation and matter; and neutron moderation, neutron diffusion, the steady-state chain reaction, and reactor kinetics.

T&AM 491–492(4910–4920) Project in Engineering Science
491, fall; 492, spring. 1–4 credits TBA.
Projects for undergraduates under the guidance of a faculty member.

T&AM 796–800(7960–8000) Topics in Theoretical and Applied Mechanics
Fall, spring. 1–3 credits TBA.
Special lectures or seminars on subjects of current interest. Topics are announced when the course is offered.

T&AM 890(8900) Master's Degree Research in Theoretical and Applied Mechanics
Fall, spring. 1–15 credits TBA. S-U grades.
Thesis or independent research at the M.S. level on a subject of theoretical and applied mechanics. Research is under the guidance of a faculty member.

T&AM 990(9900) Doctoral Research in Theoretical and Applied Mechanics
Fall, spring. 1–15 credits TBA. S-U grades.
Thesis or independent research at the Ph.D. level on a subject of theoretical and applied mechanics. Research is under the guidance of a faculty member.

FACULTY ROSTER

Abel, John F., Ph.D., U. of California, Berkeley. Prof. (Emeritus), Civil and Environmental Engineering, Emeritus
Afshari, Ehsan, Ph.D., California Inst. of Technology. Asst. Prof., Electrical and Computer Engineering
Ahner, Beth A., Ph.D., Massachusetts Inst. of Technology. Assoc. Prof., Biological and Environmental Engineering
Albonesi, David H., Ph.D., U. of Massachusetts. Assoc. Prof., Electrical and Computer Engineering
Albright, Louis D., Ph.D., Cornell U. Prof., Biological and Environmental Engineering
Allmendinger, Richard, Ph.D., Stanford U. Prof., Earth and Atmospheric Sciences
Allmon, Warren D., Ph.D., Harvard U. Adjunct Assoc. Prof., Earth and Atmospheric Sciences
Andronicos, Christopher L., Ph.D., Princeton U. Assoc. Prof., Earth and Atmospheric Sciences
Aneshansley, Daniel J., Ph.D., Cornell U. Prof., Biological and Environmental Engineering
Anton, A. Brad, Ph.D., California Inst. of Technology. Assoc. Prof., Chemical and Biomolecular Engineering
Apanasovich, Tatiyana, Ph.D., Texas A&M U. Asst. Prof., Operations Research and Information Engineering
Apsel, Alyssa B., Ph.D., Johns Hopkins U. Clare Boothe Luce Assistant Professor of Electrical and Computer Engineering
Aquino, Wilkens, Ph.D., U. of Illinois. Asst. Prof., Civil and Environmental Engineering
Archer, Lynden A., Ph.D., Stanford U. Marjorie L. Hart '50 Professor of Engineering, Chemical and Biomolecular Engineering
Arms, William, Ph.D., U. of Sussex (U.K.). Prof., Computer Science
Ast, Dieter G., Ph.D., Cornell U. Prof., Materials Science and Engineering
Avedisian, C. Thomas, Ph.D., Princeton U. Prof., Mechanical and Aerospace Engineering
Baeumner, Antje J., Ph.D., U. of Stuttgart (Germany). Assoc. Prof., Biological and Environmental Engineering
Bailey, Graeme, Ph.D., U. of Birmingham (U. K.). Prof., Computer Science
Baker, Shefford P., Ph.D., Stanford U. Assoc. Prof., Materials Science and Engineering
Bala, Kavita, Ph.D., Massachusetts Inst. of Technology. Asst. Prof., Computer Science
Barazangi, Muawia, Ph.D., Columbia U. Prof., Earth and Atmospheric Sciences
Bartel, Donald L., Ph.D., U. of Iowa. Prof., Mechanical and Aerospace Engineering and Biomedical Engineering
Bartsch, James A., Ph.D., Purdue U. Assoc. Prof., Biological and Environmental Engineering
Bassett, William A., Ph.D., Columbia U. Prof. (Emeritus), Earth and Atmospheric Sciences
Bhave, Sunil, Ph.D., U. of California, Berkeley. Asst. Prof., Electrical and Computer Engineering
Bird, John M., Ph.D., Rensselaer Polytechnic Inst. Prof. (Emeritus), Earth and Atmospheric Sciences
Birman, Kenneth P., Ph.D., U. of California, Berkeley. Prof., Computer Science
Bisogni, James J., Ph.D., Cornell U. Assoc. Prof., Civil and Environmental Engineering
Blakely, John M., Ph.D., Glasgow U. (U.K.). Herbert Fisk Johnson Professor of Engineering, Materials Science and Engineering
Bland, Robert G., Ph.D., Cornell U. Prof., Operations Research and Information Engineering
Bloom, Arthur L., Ph.D., Yale U. Prof. (Emeritus), Earth and Atmospheric Sciences
Bojanczyk, Adam W., Ph.D., U. of Warsaw (Poland). Assoc. Prof., Electrical and Computer Engineering
Bonassar, Lawrence J., Ph.D., Massachusetts Inst. of Technology. Assoc. Prof., Biomedical Engineering and Mechanical and Aerospace Engineering
Booker, John F., Ph.D., Cornell U. Graduate School Prof. (Emeritus), Mechanical and Aerospace Engineering
Brock, Joel D., Ph.D., Massachusetts Inst. of Technology. Director and Prof., Applied and Engineering Physics
Brown, Larry D., Ph.D., Cornell U. Prof., Earth and Atmospheric Sciences
Brutsaert, Wilfried H., Ph.D., U. of California, Davis. William L. Lewis Prof. of Engineering, Civil and Environmental Engineering
Buhrman, Robert A., Ph.D., Cornell U. John Edson Sweet Professor of Engineering, Applied and Engineering Physics
Burns, Joseph A., Ph.D., Cornell U. Irving Porter Church Professor of Engineering, Theoretical and Applied Mechanics; Astronomy
Burtscher, Martin, Ph.D., U. of Colorado, Boulder. Asst. Prof., Electrical and Computer Engineering
Butcher, Jonathan, T., Ph.D., Georgia Inst. of Technology. Asst. Prof., Biomedical Engineering
Cady, K. Bingham, Ph.D., Massachusetts Inst. of Technology. Prof., Theoretical and Applied Mechanics; Nuclear Science and Engineering
Callister, John R., Ph.D., Cornell U. Kinzelberg Director of Entrepreneurship in Engineering
Campbell, Mark E., Ph.D., Massachusetts Inst. of Technology. Assoc. Prof., Mechanical and Aerospace Engineering
Cardie, Claire T., Ph.D. U. of Massachusetts, Amherst. Assoc. Prof., Computer Science
Caruana, Richard, Ph.D., Carnegie Mellon U. Asst. Prof., Computer Science
Cathles, Lawrence M. III, Ph.D., Princeton U. Prof., Earth and Atmospheric Sciences
Caughey, David A., Ph.D., Princeton U. Prof., Mechanical and Aerospace Engineering
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