THE ALBERT NERKEN SCHOOL OF ENGINEERING

MISSION STATEMENT

The Albert Nerken School of Engineering will create an educational culture with a commitment to excellence. We will bring together the best and brightest engineering students; we will nurture and develop their talents; we will encourage them to work and learn at their highest levels; and we will instill in them the desire and the ability to use their engineering background to fulfill their potential as knowledgeable, creative and responsible leaders in society.

OVERVIEW

With an average enrollment of about 550 undergraduate students, engineering is the largest of The Cooper Union's schools. The school maintains small class sizes in courses and laboratories in order to provide for personal attention. It offers bachelor of engineering (B.E.) degree programs in chemical, civil, mechanical and electrical engineering, accredited by the EAC commission of ABET[1].

In addition, the school offers an interdisciplinary engineering program (B.S.E.). This program empowers students to create their own curricula (within carefully set parameters) in those areas of engineering that cross traditional boundaries—for example, bioengineering, energy engineering, infrastructure engineering, environmental engineering, electro-mechanical engineering, robotics, etc.

The (B.S.E.) program provides an excellent preparation for graduate work in law, medicine, business, etc.

The integrated master's program offers the opportunity to earn both a bachelor's and a master's degree in an engineering discipline at The Cooper Union within four, five or six years. A thesis is required.

Another master's program is being planned; it will be for practicing professionals on a tuition basis. Also, clusters of courses may be offered toward a tuition-based graduate certificate in engineering. This is in keeping with the commitment to provide life-long learning. Both the tuition master's and certificate programs are in development.

Degree programs are designed to prepare students to enter the profession immediately after graduation or to pursue graduate study. An extraordinary number of Cooper Union engineering graduates have gone on to earn Ph.D. degrees at the nation's most prestigious graduate schools. Other graduates have gone on to study in fields such as medicine, law or business. Many of our graduates have risen to leadership positions in industry, education and government.

The early curricula in engineering are based on intensive work in the sciences, mathematics, computer science and engineering sciences, which serve as preparation for in-depth study within the various engineering fields. Building on a strong base of mathematics and sciences, and emphasizing the integration of knowledge, these curricula are concerned with an understanding of nature, the limitations of our present knowledge and the potential for advancing that knowledge.

[1] ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012

Strong mathematical and computer skills are developed in all engineering students. This includes the ability mathematically to model and then to solve problems algorithmically, in a suitable language, and to use existing commercial packages for analysis and design. Students are expected to be fluent in at least two computer languages, and many specialized packages are used both in elective and in required courses. The faculty expect assignments to be carried out using the computer in appropriate ways, both as a design tool using packages and also as a platform for original software.

Defining characteristics of the School of Engineering's programs are the emphasis on project-based learning and opportunities for undergraduate research. Students and their peers regularly join the faculty in solving real-life problems that exist in contemporary society. Multi-disciplinary teams work together, frequently cooperating with outside professionals, who act as mentors. Superior analytical abilities and thorough grounding in engineering fundamentals and design enable students to participate with faculty members on these research projects. Their results may be published, presented at conferences or even patented.

A strong background in engineering design threads throughout the curriculum, starting with the first year. This design experience takes into consideration factors such as environmental issues, sustainability, economics, teamwork, societal impact, safety and political climate—showing students that a "design" is much more than a purely technological solution.

Some design problems are offered in collaboration with foreign universities to increase awareness of the global nature of the engineering profession (e.g., The Cooper Union's "Globetech" program). Others may involve collaboration with industry or hospitals.

Ample electives are offered so that interested students can add a background in business and entrepreneurship, additional mathematics and science or a "concentration" in an additional engineering area.

Like The Cooper Union's other schools, the Albert Nerken School of Engineering is intimately involved with the New York metropolitan area. Sometimes, the city and its infrastructure are used as a laboratory. The school also draws on the region's abundant talent and resources, including an outstanding array of engineers and scientists employed at major corporations, governmental agencies and consulting firms in the New York region. The school calls on physicians, lawyers and other specialists to collaborate in research and mentoring and to give unique insights into contemporary problems and social issues confronting modern engineers.

Students benefit from close contact with the faculty, who are devoted teachers, and the school's loyal alumni, who delight in sharing their experiences and insights with students, and in serving as role models. Our students are encouraged to participate in The Cooper Union's rich seminar and cultural programs as well as to attend talks by guest speakers. They join various appropriate professional societies, many of which have chapters at The Cooper Union. Students are inspired to qualify for membership in national engineering honor societies. They also participate in student government and sports, and take advantage of the vast cultural environment offered by New York City and the neighborhood.

In preparation for their responsibilities as engineers who are affected by the dynamics of technological advance and social change, students are exposed to and challenged in the fields of social science, humanities and other general studies.

Graduates of The Cooper Union are recruited regularly by major national and international corporations and graduate schools nationwide. Alumni are found in the top management and research leadership of many American corporations; hold key positions in federal, state and city agencies; and distinguish themselves on university faculties and administrations nationwide. Through their many and varied professional accomplishments, alumni have earned for the school its reputation for excellence.

FACILITIES AND RESEARCH

The Brooks Computer Center is available to all students and faculty. It provides a centralized administration and technological support for all academic computing needs, and allows students to take advantage of rapidly emerging hardware and software technologies. The center maintains an ample supply of computers of all major types—Intel™ based machines, Apple Macintosh™, Sun Microsystems™ IBM™ are examples. The machines are concentrated in computer classrooms, offices, laboratories, the residence hall and special centers.

The Department of Information Technology provides a wired and wireless network designed to give a rich and reliable computing environment. It is locally accessible through the intranet, which connects all but specialized stand-alone systems. Students have access to all of the major operating systems such as the varieties of Microsoft Windows™, Solaris™, Linux™ and Mac/OS™.

The Department opf Information Technology has both formal classroom instructional facilities and informal drop-in accommodations. Currently, there exist no restrictions or charges for computer time and availability of machines is widespread.

A full complement of applications, programming languages and internet tools are available. Multimedia hardware includes audio/video capture and output, print and film scanners, digital cameras, CD burners and large-format color plotters.

Data communications with the outside community are maintained via multiple dedicated high-speed internet connections. Students and faculty have access to software packages and programming languages on the local network and can download content from all internet sites worldwide. Students are expected to pay careful attention to copyright and ethical uses of the internet and to conduct themselves professionally at all times.

C.V. Starr Research Foundation The C.V. Starr Research Foundation, whose forerunner was established in 1976 as The Cooper Union Research Foundation, is a not-for-profit corporation and sponsors many of the externally funded research projects in the School of Engineering. By encouraging and supporting research, the foundation augments the educational opportunities for students, enhances professional development of faculty, promotes multi-disciplinary research and serves the community through its research and development efforts and as a sponsor of public seminars and conferences.

Participation in research activities by faculty and students is essential to the vitality of the educational programs. In attempting to meet this objective, The C.V. Starr Research Foundation plays an important role for faculty and students having research talent who wish to pursue sponsored research individually or in concert with other faculty and students. The foundation facilitates collaboration with other universities, hospitals, industry and government.

Projects undertaken by The C.V. Starr Research Foundation are externally funded. Faculty serve as project directors, assisted by other faculty members, outside consultants and undergraduate and graduate students of The Cooper Union.

The C.V. Starr Research Foundation is poised to support all programs in all of the schools at The Cooper Union, both at the undergraduate and graduate levels, by providing real-life research projects throughout the curriculum. To this end, several inter-disciplinary research centers have been developed.

Each of the centers aims to draw upon the varied faculty expertise across The Cooper Union and uses laboratory resources in the School of Engineering, as well as the resources of the Schools of Art and Architecture.

Recent research sponsors of The C.V. Starr Research Foundation include Zimmer, Pfizer, EPRI, Con Edison, the National Security Agency, the City of New York Departments of Transportation, Environmental Protection and Design and Construction, Transpo, Lucent, NYSERDA, the U.S. DOE, Lenox Hill Hospital, Verdant Technologies and The Howard Hughes Medical Institute.

The C.V. Starr Research Foundation has a proprietary interest in several new technologies, all of them patented and most of them developed at The Cooper Union. Examples include several patents in asphalt technology, a clean-coal burning technology, an innovative hydro-electric generation process, fuel-cell processes, a micro-balance sensor and several patents in telecommunications and environmental measurement devices.

The Maurice Kanbar Center for Biomedical Engineering, where research is ongoing in orthopaedic bio-mechanics, tissue engineering, rehabilitation, neurology, etc. This center has established collaborative relationships with several hospitals and medical research institutions in the New York City area.

The Center for Urban Systems and Infrastructure has started research in the areas of urban security and protective design, infrastructure rehabilitation, new energy technologies, acoustics and noise abatement and sustainable environment. Industrial partnerships have been formed with various corporations and government agencies. The Cooper Union Institute for Urban Security operates under the auspices of this center, and the following institutes are being developed:

- The Institute of Water Resources and the Environment,
- The Institute of Renewable Energy and
- The Institute for Soil Structure Interaction and the Underground Built Environment.

The Center for Materials and Manufacturing Technology will be engaged in research in composite materials, fire-resistant and blast-resistant materials, robotics, mechatronics, nano-technologies and nano-biosensors. The center will also be active in innovative product design and automation.

The Center for Signal Processing, Communications and Computer Engineering (S*PROCOM^2) engages in recent and ongoing research in biomedical signal and image processing, neuroscience, software engineering, mapping algorithms to FPGA and other specialized architectures, network security, Monte Carlo simulations and wireless communications. Other areas of interest include sensor arrays and networks, embedded control systems and cognitive systems. Partnerships and collaboration have been established with technology firms, both small and large, medical research institutions and financial firms in and around New York City.

The Center for Sustainable Engineering, Art and Architecture—Materials, Manufacturing and Minimalization (SEA^{2}M^3), which involves projects within engineering, art and architecture.

BACHELOR OF ENGINEERING CURRICULUM

The requirements for the bachelor's degree programs must be completed within four years of first registration, except with the explicit consent of the dean/associate dean. Requests for extension must be presented in writing to the dean's office prior to the sixth semester of registration (or the end of the junior year). It is the responsibility of the student to maintain normal and reasonable progress toward the degree. If courses are made up elsewhere for credit, the student is responsible for all costs incurred. Prior appropriate adviser(s) approval is required. If a student elects to take additional courses at other institutions, he or she must do so (a) with prior academic approval if transfer credit is desired and (b) at their own expense. Additionally, ABET accreditation requires:
• one year of a combination of mathematics and sciences (some with experimental experience) appropriate to the discipline
• one and a half years of engineering topics consisting of engineering sciences and engineering design appropriate to the student's field of study and.
• a general educational component that complements the technical content of the curriculum and is consistent with the program and institutional objectives.

In order to graduate, all students must meet the following conditions:
• A minimum of 135 credits are required;
• Satisfaction of all program curricula;
• Satisfaction of the residence study requirements;
• A minimum grade point average (G.P.A.) of 2.0;
• A minimum grade point average (G.P.A.) of 2.0 for the junior and senior years combined.

Humanities and Social Sciences The requirements in this area are satisfied by courses offered by The Cooper Union Faculty of Humanities and Social Sciences or by transfer credit for liberal arts courses taken at other institutions. The courses in this area are intended to provide both breadth and depth and should not be limited to a selection of unrelated introductory courses.

The Cooper Union liberal arts courses, shown elsewhere in the Faculty of Humanities and Social Sciences catalog section, have prefixes **H, S** and **HTA**. The basic courses **HSS1**–**HSS2** and **HSS3**–**HSS4** are prerequisites for all higher level courses in the same prefix family. **H** and **S** courses carry three credits each; **HTA** courses carry two credits. Engineering students should consult with the dean of Humanities and Social Sciences about choice of courses to satisfy particular interests.

Transfer credits for liberal arts courses must be approved by the dean of Humanities and Social Sciences. Courses that cannot be used to satisfy the Humanities and Social Sciences requirement are:
• language skills courses such as introductory foreign language, public speaking, report writing;
• craft and performance courses unless accompanied by theory or history;
• subjects such as accounting, finance, engineering economy, industrial management, personnel administration.

Some programs require "free electives or non-technical electives." For transfer credit for particular courses, the School of Art or the School of Architecture may be a more appropriate authority to sanction the transfer. Students who are uncertain should approach the Office of the Dean of Engineering in the first instance and be directed to the correct group of faculty.

Program Requirements The specific programs for entering students are shown in detail in the curriculum tables.

Course Substitutions and Credits A student may request to substitute for a required course or courses given in the School of Engineering provided that:
• the substitution is limited to 12 credits maximum toward the total number of credits required for graduation,
• the substitution is approved by the dean/associate dean and program adviser(s) and
• ABET accreditation requirements are not violated.

The number of academic credits for each course generally is based on the following relationship:
• 1 credit per contact hour in class
• 1⁄2 credit per contact hour of laboratory

This relationship was established on the basis that generally two hours of preparation are expected of the student for every contact hour in class or project activities and generally one hour of preparation is expected for every contact hour of laboratory. (The Chemical Engineering Department does not permit the substitution of any courses for required courses.)

Residence Study Requirement A candidate for a bachelor's degree must be enrolled during the entire academic year immediately preceding the granting of the degree and must carry at least 12 credits per semester during that period. Also, the candidate must have been enrolled for a minimum of four semesters at The Cooper Union as a full-time student for the bachelor's degree.

Honors and Special Programs

Dean's List The Office of Admissions and Records determines a Dean's List twice a year, at the end of each semester, on the basis of the record of the completed grade in every subject at the official end of the grading period. To qualify, a student must have a 3.5 or better semester grade point average for a study program of at least 12 credits during that semester with no grade lower than **C** and no grades of Incomplete (**I**).[2]

Course Overload A student having a grade point average of 3.0 or better may elect to take an overload of one course in any given semester. In all other cases of overload, approval of the student's academic adviser(s) and the written approval of the dean/associate dean of engineering must be obtained. Overload beyond 21 credits requires the written permission of the dean/associate dean and no overload is permitted for students with a prior semester G.P.A. of less than 3.0 or a cumulative G.P.A. of less than 3.0.

Graduation with Honors Each graduating senior in the School of Engineering who has achieved an overall cumulative rating of 3.8 or higher is awarded the degree with the notation summa cum laude. Magna cum laude requires a G.P.A. of 3.7 or higher and cum laude requires at least a 3.5 G.P.A.

Faculty Advisers All first-year students have the same faculty adviser. For subsequent years, students will be assigned one, two or more advisers each, appropriate to their field of study. Each student's program is established in consultation with his or her adviser(s); changes may be made only with the adviser(s)'s approval. Advisers for IDE and BSE students will be assigned according to the student's educational interests and goals.

Curricular Transfers Students wishing to change their course of study should first discuss their interests with the current adviser(s) in both the current and the new speciality areas. Transfer is at the discretion of the dean's office and the receiving department or the BSE committee. It may be affected by the student's grades and availability of program resources. It becomes effective when the required petition form, approved the dean or associate dean of engineering, has been delivered to the Office of Admissions and Records. First-year students may not change their area of study until the end of the year when two semesters' grades are available. A G.P.A. of 3.0 or better is required for approval to transfer curriculum.

Transfer Credit Students, at their own expense, desiring to register for courses at another institution for transfer credit to The Cooper Union must have appropriate advance approval. For courses in mathematics, sciences or engineering, this approval is to be obtained from:

• the department responsible for the course at The Cooper Union and

• the dean or associate dean of engineering.

For liberal arts courses, approval is to be obtained from the dean of Humanities and Social Sciences. In order that transfer credits from another school be accepted, a grade of **B**[3] or better is required. An exception may be granted in special circumstances only upon formal appeal to the Committee on Academic Standards.

Transfer credit is never granted for paid summer internships or work experience or paid or unpaid research.

Pre-Medical, Pre-Law or Pre-Business Studies Upon completion of the engineering degree, some graduates may decide to attend medical, dental, business or law school. Most of the prerequisites for such a course of action are offered at The Cooper Union. For medical school or dentistry, students are advised to take one year of organic chemistry and one year of biology. For law or business, additional economics, political science and professional ethics courses are useful. Students should consult their adviser(s).

Study Abroad The Cooper Union offers suitably qualified, approved students the opportunity to participate in research programs at various foreign universities during the summer. For example, students have attended universities in England, Ireland, Scotland, Australia, Hong Kong, Germany, China, Japan, Italy, Spain, Ghana and France. Cooper Union credit (up to six credits at the 300 level) is granted upon successful completion of the research work, presentation of a written report and its approval by the Office of the Dean. Applications are available in the dean's office in mid-January. (Students on probation are ineligible for this program). Credit is only allowable for exchange programs authorized by The Cooper Union School of Engineering.

Professional Development Mastering the technical aspects of an engineering field is only part of being a successful engineer. There are many other areas that go toward building and continuing a professional career.

The School of Engineering has established the **Aba and Leja Lefkowitz Program for Professional Development** to strengthen the non-technical attributes required of its engineering undergraduates. Under this umbrella, a number of successful Cooper Union initiatives have been consolidated to provide a comprehensive program of experiences and training for all engineering undergraduates.

[2] Students may petition the dean/associate for reconsideration in the Dean's List after the Incomplete (I) has been made up.

[3] A grade of B- cannot be ttransferred

This training is provided through zero-credit courses of seminars and workshops that span a student's career at The Cooper Union. Attendance at the seminars and workshops is mandatory for engineering freshmen and sophomores. The courses are designed to introduce students to the profession of engineering, as well as deal with their professional development. The Cooper Union's **CONNECT** (**C**ooper's **O**wn **N**o **N**onsense **E**ngineering **C**ommunication **T**raining) program is an integral part of these courses and provides intensive, regular training in effective communication. A wide range of topics are covered (in addition to communication skills) including ethics, environmental awareness, life-long learning, career development, conflict resolution, entrepreneurship, marketing, workplace issues, professional societies, professional licensure, organizational psychology, teamwork skills, etc. These topics are dealt with using methods such as case studies, role playing and interactive activities—"learning by doing." In addition, guest professionals, experts and alumni participate where appropriate.

These experiences make students aware of the importance of the non-technical skills needed for professional success. Through this program students are given significant help in easing the transition into the workplace and ensuring success there.

Engineering Advisory Council

The School of Engineering is advised in key engineering issues, such as leadership, ethics, communication skills, entrepreneurship and corporate responsibility, by its Advisory Council, which is comprised of company presidents, C.E.O.s, Nobel Laureates, engineers, physicians, attorneys and other business and professional experts. The Council meets annually with faculty and students to discuss important issues in engineering education. In addition, the Technology Transfer Advisory Committee is made up of appropriate individuals to advise students and faculty about issues such as patents, commercialization of inventions, entrepreneurship, etc.

Gateway Engineering Education Coalition

The Cooper Union participated in the National Science Foundation (NSF)–sponsored Gateway Engineering Education Coalition with Columbia University, Polytechnic University, New Jersey Institute of Technology, Drexel University, Ohio State University and the University of South Carolina. The object of the coalition was curricular innovation and exploration of new pedagogical methods. Participation has had a strong influence on teaching, learning and assessment methodologies at the School of Engineering. A process of continuous quality improvement is in place.

ACADEMIC STANDARDS

Academic Integrity

Plagiarism is the presentation of another person's "work product" (ideas, words, equations, computer code, graphics, lab data, etc.) as one's own. Whether done intentionally or unintentionally, plagiarism will not be tolerated in the School of Engineering.

There are many types of plagiarism, some of which are listed below. (The list is not exhaustive. Speak with the appropriate faculty member or the dean or associate dean of engineering if you are uncertain as to what constitutes ethical conduct in a particular situation.)

You are plagiarizing if:

- You present as your own work product a homework assignment, a take-home exam or a class project that includes the efforts of other individuals. The contributions of other individuals (if permitted by your instructor) must be acknowledged in writing on the submitted assignment, exam or project.
- You copy the work of other students on an in-class examination or communicate with other individuals in any fashion during an exam.
- You submit as part of a homework assignment, take-home exam or class project material that has been copied from any source (including, but not limited to, a textbook, a periodical, an encyclopedia, the internet) without properly citing the source, and/or without using quotation marks. It is also prohibited to submit such materials in a minimally altered form without proper attribution. Improperly copied material might include text, graphics (computer or otherwise), computer source code, etc.

Other prohibited acts of academic dishonesty include (but are not limited to):

- Attempting to obtain a copy of an examination before it is administered.
- Dishonesty in dealing with a faculty member or a dean, such as misrepresenting the statements of another faculty member.
- Bringing notes into an examination when forbidden to do so.
- Bringing any device into an examination (computer/ PDA/calculator), which permits the retrieval of examination-related materials unless expressly permitted by the instructor.
- Bringing any device into an examination that allows communication with other individuals or computers or computer databases unless expressly permitted by the instructor.

Faculty members may not unilaterally resolve incidents of academic dishonesty. Each faculty member is required to report all cases of plagiarism or academic dishonesty to the engineering dean's office on an Academic Integrity Incident form. If documentary evidence of the incident exists, it should be attached to the form. The dean's office, in consultation with the faculty member and the student, will select from the following sanctions: a grade of **F** for the assignment,a grade of **F** for the course or dismissal of the student from the school. A record of all incident forms will be kept in the dean's office and second-time offenders are candidates for dismissal from the school. Students who are dismissed because of academic dishonesty should be aware that incident reports and any responsive actions by the dean's office or Academic Standards Committee become part of their permanent record.

Sexual or Racial Harassment

Such behavior will not be tolerated. Incidents should be reported immediately. Students should see the dean or associate dean, and also the dean of students as soon as possible.

Code of Conduct

Students are required to read and abide by the code of conduct published by the Office of Student Services.

GRADES OF RECORD

The definitions below deal with the student's attainment in the formal work of the subject. Nevertheless, it should be understood that such essential qualities as integrity, adherence to class regulations, enthusiasm, motivation, clarity in presentation of work and sense of obligation, together with ability to use the English language correctly and intelligibly, are reflected in the grade. The course grade is assigned by the instructor in conformity with definitions indicated in this section.

The grade **A** indicates a superior and comprehensive grasp of the principles of the subject. It denotes an ability to think quickly and with originality toward the solution of difficult problems.

The grade **B** indicates evidence of a good degree of familiarity with the principles involved in the subject. It implies less originality and a tendency to hold to patterns of thought presented in the formal subject matter.

The grade **C** indicates an average knowledge of the principles involved in the subject and a fair performance in solving problems involving these principles. This grade implies average ability to apply the principles to original problems.

The grade **D** indicates a minimum workable knowledge of the principles involved in the subject. This grade denotes low achievement and therefore the number of such grades permitted any student is limited in a manner prescribed by the section on Scholastic Standards.

The grade **F** indicates unsatisfactory understanding of the subject matter involved. A grade of **F** may be made up only by repeating the subject in class; both the new grade and the new credits and the original grade and credits are included in the permanent record and in the grade point average. A student who receives an **F** grade in a repeated course is a candidate for dismissal by the school's Academic Standards Committee.

The Incomplete (I) Grade

The designation of **I** indicates that the work of the course has not been completed and that assignment of a grade and credit has been postponed. This designation will be given only in cases of illness (confirmed by authorized physician's letter) or of other documented extraordinary circumstances beyond the student's control. The **I** designation will be given only with the approval of the dean or associate dean of engineering. At the time of submission of an **I** designation, the instructor will indicate whether the student's progress to that point has been satisfactory or unsatisfactory, offering an estimation of grades whenever possible as a means of assisting the Committee on Academic Standards in their deliberations.

The deadline for removal of an **I** designation will be determined by the instructor, but will not be later than six weeks after the start of the spring semester for students who receive such a designation in the fall semester and not later than two weeks after the start of the fall semester for students who receive such a designation in the spring semester. If the **I** is not removed within the set time limit, either by completing the work in the subject or by passing a re-examination, the I will automatically and irrevocably become an **F** unless the dean or associate dean of engineering, in consultation with the instructor, extends the time or the student withdraws from the school.

Dropped Courses and Withdrawals

Change of Program, 1st and 2nd week See General Regulations, page 15. Dropping a course during this period of classes constitutes a program adjustment. The course will not be entered on the transcript.

Adding Courses, including independent study, may not be added after the second week.

Dropping Courses, weeks 3–8. A student anticipating inability to continue an assigned program should immediately seek counseling. A student's program may be adjusted at the discretion of and after conference with the adviser(s) and the dean or associate dean of engineering, but only in cases where scholastic performance is handicapped by conditions beyond the control of the student, such as health or home conditions. This should be done during the first eight weeks of the term.

The designation **W** indicates that the student has withdrawn from the course. For credit, the course must be repeated.

Dropping Courses after the 8th week A student may lighten his or her academic load and receive a **W** grade after the eighth week of classes only with the approval of the course instructor, the adviser(s) and the dean/associate dean. It is the policy of the faculty and the Office of the Dean of Engineering not to approve any withdrawal after the eighth week of classes except under extreme, extenuating circumstances. The designation **WU** indicates that the student has withdrawn from a course without permission of the dean or associate dean of engineering and notification of the dean of Admissions and Records. However, the instructor is free to record an **F** grade in such cases; the **W** grade is not applicable.

Repeating a Course When a course is repeated (due to failure or any other reason), the grade earned each time the course was repeated is calculated into the G.P.A.

Grade Point Average or Ratings To determine academic ratings, numerical equivalents are assigned to grades as follows: A is represented by 4, B by 3, C by 2, D by 1 and F by 0. The sum of the products of credits attempted and grade equivalents earned in a period at The Cooper Union, divided by the sum of credits for that period, is the rating for that period.

Only Cooper Union grades of **A**, **B**, **C**, **D** and **F** will be used in determining ratings. Grades from other colleges and other designations such as **I** and **W** are not used in Cooper Union ratings.

Grade Changes A change in an official grade of record, other than the designation **I**, cannot be made by the dean of Admissions and Records without the express consent of the dean or associate dean of engineering. Grade changes will not be accepted after one year has elapsed from the completion of the course.

Final Examinations Final examinations are held in most subjects. They sometimes are not held in subjects whose content does not readily lend itself to formal examination, such as laboratory or project work. In certain other subjects, the class record may be ample for determining student standing. The decision on giving a final examination in a given subject is made by the instructor.

Academic Probation, Withdrawal, Dismissal Probation is the consequence of unsatisfactory scholarship. It is a warning that may involve a compulsory reduction of academic load, interviews with an assigned adviser and additional academic counseling. A student on academic probation must fulfill conditions as prescribed by the Committee on Academic Standards.

- A student whose semester grade point average is 1.5 and below is on automatic probation and is a candidate for dismissal by the Committee.
- A student whose semester grade point average falls between 1.6 and 2.0 is on automatic probation. Two semesters of automatic probation may cause the student to be a candidate for dismissal by the Committee.
- Estimates of grades in subjects with **I** designations may be included in all Committee deliberations.
- Students who fail to register will have their records annotated: "Dropped: Failure to Register."
- A student who is obliged to leave school for one semester or one year must petition the dean or associate dean of engineering for permission to withdraw. If a medical situation is a factor, consultation with the dean of students may be required. A student who has withdrawn may apply for readmission to the appropriate department and to the dean or associate dean of engineering. A change

in circumstances that indicates that the educational program may be resumed with a probability of success must be demonstrated. If a medical situation existed, consultation with the dean of students is also required.) Furthermore, medical certification of fitness to resume study will probably be required by the Office of the Dean of Engineering.

• A student who wishes to return after an absence of more than two semesters must apply for readmission to the Committee on Academic Standards.

• The records of all first- and second-year students will be reviewed by the associate dean of engineering for recommendations to the Committee on Academic Standards for appropriate action. Students who have not completed satisfactory progress toward their degree may be excluded from the third year and may be required to withdraw from The Cooper Union in order to complete course work elsewhere at their own expense.

• The Committee on Academic Standards reserves the right to determine probation and/or dismissal at any point in a student's career for appropriate academic reasons.

• Students who believe that a modification of their status should be made because of extenuating circumstances may petition, in writing, to the Committee on Academic Standards.

MASTER OF ENGINEERING CURRICULUM

The integrated bachelor/master of engineering program is intended to integrate work at the undergraduate and graduate levels and prepare graduates for entry into the engineering profession at an advanced level or for further graduate study. It affords diversification and versatility by requiring a student to elect a field of study—the major—offered in the School of Engineering, and a minor in a different field of engineering or science; this provides depth and breadth. The school offers master's degrees in chemical engineering, civil engineering, electrical engineering and mechanical engineering. An interdisciplinary master's degree program is being developed.

The faculty have determined that IDE and BSE graduates are eligible for admission to the graduate program. Such graduating students must join the chemical, civil, electrical or mechanical programs, and may be required to "make up" fundamental courses by the department.

The faculty have determined that BSE graduates are eligible for admission to the graduate program. Such graduating students must join the chemical, civil, electrical or mechanical programs, and may be required to "make up" fundamental courses by the department.

Admission Procedure Please refer to the "Application and Admission Information" section, page 8.

General Requirements

Applicants are expected to have a superior undergraduate record and to have given evidence of ability for independent work. Students are accepted on an academically competitive basis subject to the availability of an adviser and of suitable available facilities.

Cooper Union Undergraduates To be eligible for admission to the integrated bachelor/master program, one must be a currently enrolled Cooper Union undergraduate, with a minimum 3.0 grade point average according to the major. For BSE students, a 3.0 grade point average is required in all engineering courses. Consult with the program faculty. Generally, students entering The Cooper Union undergraduate programs as first-year students require four, five or six years to complete the integrated bachelor/master of engineering program.

Specific admission requirements may be waived upon recommendation of the faculty in the area of the student's major interest.

It is planned that, in the future, all master's students not in the integrated bachelor/master program will be admitted on a tuition-paying basis. This includes former graduates of The Cooper Union as well as graduates from other ABET-accredited programs. Admitted students may be required to register for advanced engineering courses to make up for any deficiencies in their preparation.

Certificate Programs The School of Engineering is developing packages to be offered to practicing professionals in various areas upon completion of 12 graduate credits. All students in certificate programs will be required to pay tuition.

COURSE DESIGNATION

The designation of a course offered in the School of Engineering uses an alphabetical prCourse Designationefix and a three-digit numbering system. The first digit usually denotes:

(1, 2) lower level undergraduate courses,
(3) advanced undergraduate courses and
(4) graduate courses.

Course Prefix

Biology	Bio
Chemical Engineering	ChE
Chemistry	Ch
Civil Engineering	CE
Computer Science	CS
Electrical Engineering	EE, ECE
Engineering Sciences	ESC
Interdisciplinary Engineering	EID
Mathematics	Ma
Mechanical Engineering	ME
Physics	Ph

Students should consult official class schedules for courses offered in a given semester. There is no assurance that a course listed in this catalog will be given every year.

Be advised that each school at The Cooper Union offers certain electives that are open to all students; consult each school's course listing.

Unless otherwise indicated, credit listings are for single semesters.

Courses are not generally offered in the summer.

Definitions

• A *free elective* is any course for which a student is qualified given within The Cooper Union.
• The status *advanced engineering elective* is to be determined by the adviser(s) and the Office of the Dean. Normally, such courses will require prerequisites and are usually taken by juniors, seniors or graduate students.
• A *core elective* is defined as any course required in either the first, second or third year of the CE, ChE, EE or ME programs.
• A minimum of 12 credits of engineering electives must be at an advanced level.

CHEMICAL ENGINEERING DEPARTMENT AND PROGRAM

FACULTY

Brazinsky (chair), Davis, Lepek, Okorafor, Stock

MISSION STATEMENT

The Cooper Union's Department of Chemical Engineering is committed to the development and graduation of engineering professionals. The department will promote student learning and understanding of science and engineering fundamentals and guide and encourage the application of this knowledge to the ethical, professional practice of chemical engineering. This will be undertaken in an environment that is responsive to new technologies, and that encourages life-long learning and research.

Program Objectives

• Our chemical engineering graduates will understand the fundamentals of science and engineering and their use in the application of chemical engineering.
• Our graduates will have an understanding and awareness of the professional, ethical and safe application of their knowledge.
• Our graduates will grasp the concept of life-long learning and appreciate the continuing development of new technologies and issues in the professional field.
• Our graduates will transition easily into their professional careers and demonstrate success in that role.
• Those graduates who pursue graduate studies and research at The Cooper Union and/or other institutions will have the necessary technical background, support and preparation to succeed.

The education of the chemical engineer requires a strong foundation in chemistry and physics, which must be applied through the medium of mathematics to the solution of design problems. A thorough knowledge is required of chemical structures, together with energy and kinetic relationships of chemical reactions and molecular transfer. The chemical engineer deals with the application of these principles to processes carried out on a variety of scales from micro-reactors to an industrial scale, in which matter undergoes changes in physical state, chemical composition or energy content. Emphasis is placed on developing creative ability. Facts and theories are presented primarily to stimulate further thought and study in all fields of chemical engineering.

Formal instruction is supplemented by visits to several plants and companies where the contribution of engineers can be observed and understood with respect to equipment, utilities, safety, costs, environmental impact, labor and supervision. The students gets first-hand experience in the chemical engineering laboratory in applying engineering analysis to equipment performance, and in learning limitations of theoretical concepts. In the senior year, the student learns how to design chemical plants from fundamental data on new processes and to recognize areas of limited knowledge from the results of the design, and thus recommend pilot plant studies, if necessary.

Chemical engineering graduates find employment in a wide variety of areas. In addition to the chemical and petroleum industries, chemical engineers are involved heavily in the biomedical, materials and environmental fields. A chemical engineering education can also be easily applied to other interdisciplinary areas such as biochemical and biomedical engineering, energy resources, environmental engineering and materials resources. As a result, chemical engineers are also finding employment in non-industrial institutions such as government, research think-tanks, policy study groups and even publishing companies.

Note that the chemical engineering department does not make use of the 12-credit rule.

Minors

A minor can be obtained by a student in chemical engineering taking any four (4) classes in one of the fields below. The courses listed are examples of courses currently in the Cooper Union catalog. Note that some may require prerequisites or permission of the instructor. Additionally, note that it will not be necessary to obtain a minor in any field in order to graduate with a bachelor of engineering in chemical engineering.

Environmental Engineering

ChE 340/Industrial Waste Treatment, CE 141/Environmental Systems Engineering, CE 142/Water Resources Engineering (also EID 142), CE 346/Hydraulic Engineering, EID 141/Air Pollution Control Systems, CE 414/Solid Waste Management, CE 435/Geo-Environmental Engineering (also EID 435), CE 440/Industrial Waste Treatment Design, CE 441/Water and Wastewater Technology, CE 446/Pollution Prevention or Minimization, CE 447/Stream and Estuary Pollution, CE 449/Hazardous Waste Management.

Biomedical Engineering

ECE 343/Bio-instrumentation and Sensing, , EID 121/Biotransport Phenomena, EID 122/Biomaterials, EID 123/Biosystems and Instrumentation, EID 124/Bioengineering in Safety Design and Injury Analysis and Prevention, EID 125/Biomechanics, EID 320/

Special Topics in Bioengineering, EID 325/Science and Application of Bioengineering Technology, EID 326/Ergonomics, EID327/Tissue Engineering, Ch 340/Biochemistry (also Bio 102), Bio 101/Molecular and Cellular Biology, ECE 422/ Selected Topics in Embedded Systems, ME 421/Rehabilitation Engineering (also EID 421), ME 423/Measurement of Human Performance (also EID 423), EID 424/Bioengineering Applications in Sports Medicine, Ch 440/Biochemistry II.

Energy Engineering

ME 131/Energetics (also EID 131), ME 133/Air-Conditioning, Heating and Refrigeration (also EID 133), ME 330/ Advanced Engine Concepts, ME 334/Combustion (also EID 334), ChE 421/Advanced Chemical Reaction Engineering, ChE 434/Special Topics in Combustion (also ME 434), ChE 435/Transport Processes in Internal Combustion Engines (also ME 435), ECE 422/Selected topics in Embedded Systems, Ph 462/Nuclear Physics.

Applied Chemical Technology

ChE 311/Introduction to Polymer Technology, ME 313/ Science of Materials for Engineering Design (also EID 313), ME 314/Introduction to Composite Materials (also EID 314), Ch 364/Solid State Chemistry, Ph 319/Introductory Quantum and Solid State Physics, ChE 411/Polymer Technology and Engineering, ME 410/Materials, Manufacturing Process (also EID 410).

Note: You will be given a letter by the chemical engineering Department certifying that you have completed a minor.

Graduate Program

In addition to advanced courses in chemical engineering and other areas, the student must complete a thesis for the M.E. degree. The candidate must choose a full-time Cooper Union faculty member from either the chemistry or chemical engineering department as one of his or her thesis advisers. Before choosing a thesis topic, however, the student should explore various professors' research interests. Research interests of chemical engineering faculty members include non-Newtonian flow, crystal growth from high-temperature melts, polymer extrusion, heat and mass transfer with change of phase, drag coefficients in dense phase transport, construction of a database of engineering materials, mathematical modeling of bio-heat transfer in micro-circulation, mathematical modeling of whole-body heat transfer, analysis of oxygen transport in the cardiovascular system and an integrated gasification process for the simultaneous disposal of sludge and garbage with concomitant production of steam and electricity, biochemical separation, protein-purification, environmental engineering and mathematical modeling, evaluation of sustainability, batch process design and optimization, pollution prevention and mitigation, infinite linear programming, nano-materials and energy systems and processes.

Chemical Engineering Program

Freshman Year	**Credits**
Fall Semester:	
ESC000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Introduction to Computer Science	3
HSS 1 Literary Forms and Expressions	3
Total Credits Fall Semester	18
Spring Semester:	
ESC000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ph 112 Physics I: Mechanics	4
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
HSS 2 Texts and Contexts: Old Worlds and New	3
Total Credits Spring Semester	15.5

Sophomore Year	**Credits**
Fall Semester:	
ESC000.3 Professional Development Seminar	0
ESC 170 Energy and Material Balances	3
Ma 223 Vector Calculus	2
Ma 224 Probability	2
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Laboratory	1.5
Ch 231 Organic Chemistry I	3
HSS 3 The Making of Modern Society	3
Total Credits Fall Semester	18.5
Spring Semester:	
ESC000.4 Professional Development Seminar	0
Ma 240 Ordinary and Partial Differential Equations	3
Ph 214 Physics III: Optics and Modern Physics	3
Ch 232 Organic Chemistry II	2
Ch 233 Organic Chemistry Laboratory	2
ESC 130.1 Chemical Engineering Thermodynamics	3
HSS 4 The Modern Context: Figures and Topics	3
Total Credits Spring Semester	16

Junior Year	Credits
Fall Semester:	
EE 121 Basic Principles of Electrical Engineering	2
Ch 251 Instrumental Analysis Laboratory	2
Ch 261 Physical Chemistry I	3
ChE 131 Advanced Chemical Engineering Thermodynamics	3
ESC 140 Fluid Mechanics and Flow Systems	3
Engineering or Science Elective	3
Total Credits Fall Semester	16
Spring Semester:	
Ch 262 Physical Chemistry II	2
ChE 121 Chemical Reaction Engineering	3
ChE 141 Heat Transmission	3
ChE 151 Process Simulation and Mathematical Techniques for Chemical Engineers	3
Engineering or Science Elective	3
Free Elective	3
Total Credits Spring Semester	17

Senior Year	Credits
Fall Semester:	
ChE 162.1 Chemical Engineering Laboratory I	1.5
ChE 161.1 Process Evaluation and Chemical Systems Design I	3
ChE 142 Mass Transfer Processes	4
ChE 152 Chemical Process Dynamics and Control	3
Engineering or Science Elective	3
Humanities/Social Sciences Elective	3
Total Credits Fall Semester	17.5
Spring Semester:	
ChE 162.2 Chemical Engineering Laboratory II	1.5
ChE 161.2 Process Evaluation and Chemical Systems Design II	3
ESC 110.1 Materials Science for Chemical Engineers	3
Engineering or Science Elective	3
Free Elective	3
Humanities/Social Sciences Electives	3
Total Credits Spring Semester	16.5
Total credits required for degree	**135**

CIVIL ENGINEERING DEPARTMENT AND PROGRAM

FACULTY

J. Ahmad (Chair), Cataldo, Guido, Tzavelis, Yapijakis

MISSION STATEMENT

To prepare our students as civil engineering professionals who will have the depth and breadth of knowledge, sense of social and ethical responsibility, commitment to a safe environment and a desire to serve the society in leadership positions.

Program Objectives

• Our civil engineering graduates will engage in life-long learning to stay abreast of the latest body of knowledge and professional practices in civil engineering and allied disciplines throughout their careers.
• Our graduates will excel in teamwork, interdisciplinary concepts, organizational skills and problem-solving methodologies in their professional careers.
• Our graduates will attain positions of leadership as professional practitioners, government officials, academicians, inventors, researchers, etc. during their professional careers.
• Our graduates will have a strong sense of commitment to excellence, independent thinking, innovation and modern professional practices throughout their careers.

Program description

Civil engineering, earliest of the engineering professions, has evolved into a broad spectrum of specialities: structural, geotechnical, hydraulic, environmental, transportation, urban planning, construction management, sustainable design, urban security and infrastructure rehabilitation. Depending on his or her interests and abilities, the modern civil engineer also may become involved in research, design and development related to projects in alternative energy sources, space structures, protection against natural and man-made disasters, etc. The civil engineer also studies and develops new materials, new structural systems and new strategies for optimizing design. Basic research, especially in the areas of applied and experimental mechanics, often arises either as a preliminary or adjunct requisite to these studies.

The civil engineer who wishes to practice creatively in any of these fields must be thoroughly grounded in the basic sciences, mathematics and applied mechanics, structures and structural mechanics, engineering sciences and computer applications.

The members of the civil engineering faculty are actively engaged in research in their specialities, which include modern advances in structural engineering and materials, geotechnical engineering, alternative energy sources, green design of buildings, water pollution control technologies, water resources engineering and urban security.

Within the civil engineering program, students may elect to pursue specialized study through an appropriate choice of electives in two areas:

- Structural and Geotechnical Engineering
- Water Resources and Environmental

Graduate level courses in these areas are available to seniors with superior academic records as indicated in the following lists:

Structures and Geotechnical Engineering: CE 422, CE 425, CE 426, CE 427, CE 428, CE 431, CE 432, CE 433, CE 434, CE 450, CE 470.

Water Resources and Environmental Engineering: CE 414, CE 440, CE 441, CE 442, CE 443, CE 444, CE 445, CE 446, CE 447, CE 448, CE 449.

Graduate Program

Completion of the master of engineering degree program in civil engineering is important for entry into the profession in any of the specialized areas discussed above. The civil engineering department offers many graduate level courses in the cited areas, such as structural engineering and environmental engineering. Graduate minors may include computer engineering, civil engineering management and others. Also recognized are minors in interdisciplinary areas of engineering.

Civil Engineering Program

Freshman Year	**Credits**
Fall Semester:	
ESC000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Introduction to Computer Science	3
HSS 1 Literary Forms and Expressions	3
Total credits fall semester	18
Spring Semester:	
ESC000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ph 112 Physics I: Mechanics	4
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
HSS 2 Texts and Contexts: Old Worlds and New	3
Total credits spring semester	15.5

Sophomore Year	**Credits**
Fall Semester:	
ESC000.3 Professional Development Seminar	0
Ma 223 Vector Calculus	2
Ma 224 Probability	2
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Laboratory	1.5
ESC 100 Engineering Mechanics	3
ESC 110 Materials Science	3
HSS 3 The Making of Modern Society	3
Total credits fall semester	18.5
Spring Semester:	
ESC000.4 Professional Development Seminar	0
ESC 120 Principles of Electrical Engineering	3
Ma 240 Ordinary and Partial Differential Equations	3
Ph 214 Physics III: Optics and Modern Physics	3
ESC 101 Solid Mechanics	3
CE 120 Fundamentals of Civil Engineering	3
HSS 4 The Modern Context: Figures and Topics	3
Total credits spring semester	18

Junior Year	**Credits**
Fall Semester:	
CE 121 Structural Engineering	4.5
CE 141 Environmental Systems Engineering	4.5
ESC 130 Engineering Thermodynamics	3
ESC 140 Fluid Mechanics and Flow Systems	3
Humanities/Social Sciences Elective	3
Total credits fall semester	18
Spring Semester:	
CE 122 Structural Engineering II	3
CE 131 Introduction to Geotechnical Engineering	4.5
CE 142 Water Resources Engineering	4.5
CE 341 Design of Steel Structures	3
Humanities/Social Sciences Elective	3
Total credits spring semester	18

Senior Year	**Credits**
Fall Semester:	
CE 342 Design of Reinforced Concrete Structures	3
CE 351 Urban Transportation Planning	3
CE 363 Civil Engineering Design I	3
Engineering or Science Electives	6
Total credits fall semester	15
Spring Semester:	
CE 361 Civil Engineering Experimental Projects	2
CE 364 Civil Engineering Design II	3
Engineering or Science Electives	9
Total credits spring semester	14

Total credits required for degree	**135**

ELECTRICAL ENGINEERING DEPARTMENT AND PROGRAM

FACULTY

H. Ahmad, Baum (Dean), Ben-Avi (Associate Dean), Chatterjee, Cumberbatch, Fontaine (Chair), Keene, Kirtman, Sable

MISSION STATEMENT

To develop a highly trained, consummate engineer: able to lead, to practice in a professional manner, to grow with technological advances, to express himself or herself in written and in oral form, to function as a project engineer immediately upon graduation and to pursue graduate studies in a variety of professional fields.

Program Objectives

Each of our electrical engineering graduates:
• will be capable of functioning as a first-class project engineer,
• will have exceptional technical knowledge and professional design skills,
• will be capable of professional-level written and oral expression.
• will be capable of demonstrating leadership skills and
• will be open-minded and receptive to new ideas and viewpoints, with a commitment to excellence, independent thinking, research, life-long learning, innovation and the use of the latest technologies and modern professional practices throughout his or her career.

Program description

Basic courses in electrical circuits and signal processing (or computer systems or computer engineering), along with core mathematics, science and humanities courses, are taken in the freshman and sophomore years. Students may then elect to pursue study through an appropriate choice of electives in three areas:
• Electronic Systems and Materials
• Signal Processing and Communications
• Computer Engineering

Students plan their electives with the assistance of a faculty adviser to specialize in areas of interest and to obtain a well-rounded and diverse educational experience. By the senior year, strong students are encouraged to take graduate-level electives beyond the requirements of the bachelor's degree as part of an integrated five-year master's program.

The curriculum interweaves strong theory, grounded in mathematics and science, with extensive use of CAD tools and practical projects. Team and individual projects begin in the freshman year and culminate with year-long senior projects.

All laboratory courses, and many recitation courses, are project based. By the time students commence their senior projects, they perform open-ended system design, implementation and testing, cost analysis and prepare written and oral presentations. They act as project managers under the guidance of a faculty adviser.

There are numerous research and independent study opportunities involving close work with faculty and practicing professionals on cutting-edge problems.

Graduate Program

The candidate must choose a full-time Cooper Union faculty member from the electrical engineering department as one of his or her advisers. Possible areas of concentration or thesis topics are numerous and reflect the diverse interests of the faculty. Some examples are digital signal processing, image and video processing, biomedical engineering, wireless communications, computer networks, machine learning, mapping algorithms to architecture, advanced computing and simulation methodology, electronic materials, integrated circuit engineering and sustainable engineering. Thesis topics that are research-oriented or targeted towards commercial application are particularly encouraged.

Web Site

The Electrical Engineering program maintains a web site at www.ee.cooper.edu.

Electronic Systems and Materials Track in Electrical Engineering

Freshman Year	Credits
Fall Semester:	
ESC000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Introduction to Computer Science	3
HSS 1 Literary Forms and Expressions	3
Total Credits Fall Semester	18
Spring Semester:	
ESC000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ph 112 Physics I: Mechanics	4
ECE 150 Digital Logic Design	3
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
HSS 2 Texts and Contexts: Old Worlds and New	3
Total Credits Spring Semester	18.5

Sophomore Year	Credits
Fall Semester:	
ESC000.3 Professional Development Seminar	0
ECE 141 Circuits & Electronics I	3
Ma 223 Vector Calculus	2
Ma 240 Ordinary and Partial Differential Equations	3
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Laboratory	1.5
HSS 3 The Making of Modern Society	3
Total Credits Fall Semester	16.5
Spring Semester:	
ESC000.4 Professional Development Seminar	0
ECE 110 MATLAB Seminar: Signals and Systems	0
ECE 111 Signal Processing & Systems Analysis	3
ECE 131 Solid State Materials	3
ECE 151 Computer Architecture	3
Ma 224 Probability	2
Ph 214 Physics III: Modern Physics	3
HSS 4 The Modern Context: Figures and Topics	3
Total Credits Spring Semester	17

Junior Year	Credits
Fall Semester:	
ECE 101 Communication Theory	3
ECE 114 Digital Signal Processing	3
ECE 121 Control Systems	3
ECE 142 Circuits and Electronics II	3
ECE 193 Electrical & Computer Engineering Projects I	1.5
Ma 326 Linear Algebra	3
Humanities/Social Sciences Elective	3
Total Credits Fall Semester	19.5
Spring Semester:	
ECE 103 Communication Networks	3
ECE 135 Engineering Electromagnetics	4
ECE 194 Electrical & Computer Engineering Projects II	4
ECE 341 Integrated Circuit Design	3
Humanities/Social Sciences Elective	3
Total Credits Spring Semester	17

Senior Year	Credits
Fall Semester:	
ECE 195 Electrical & Computer Engineering Projects III	4
Non-technical Elective	3
Engineering or Science Electives	7
Total Credits Fall Semester	13
Spring Semester:	
ECE 196 Electrical & Computer Engineering Projects IV	3
Non-technical Elective	3
Engineering or Science Electives	8.5
Total Credits Spring Semester	14.5

Total credits required for degree **135**

Signal Processing and Communications Track in Electrical Engineering

Freshman Year	Credits
Fall Semester:	
ESC000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Introduction to Computer Science	3
HSS 1 Literary Forms and Expressions	3
Total Credits Fall Semester	18
Spring Semester:	
ESC000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ph 112 Physics I: Mechanics	4
ECE 150 Digital Logic Design	3
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
HSS 2 Texts and Contexts: Old Worlds and New	3
Total Credits Spring Semester	18.5

Sophomore Year	Credits
Fall Semester:	
ESC000.3 Professional Development Seminar	0
ECE 141 Circuits & Electronics I	3
Ma 223 Vector Calculus	2
Ma 240 Ordinary and Partial Differential Equations	3
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Laboratory	1.5
HSS 3 The Making of Modern Society	3
Total Credits Fall Semester	16.5
Spring Semester:	
ESC000.4 Professional Development Seminar	0
ECE 110 MATLAB Seminar: Signals and Systems	0
ECE 111 Signal Processing & Systems Analysis	3
ECE 131 Solid State Materials	3
ECE 151 Computer Architecture	3
Ma 224 Probability	2
Ph 214 Physics III: Modern Physics	3
HSS 4 The Modern Context: Figures and Topics	3
Total Credits Spring Semester	17

Junior Year	Credits
Fall Semester:	
ECE 101 Communication Theory	3
ECE 114 Digital Signal Processing	3
ECE 121 Control Systems	3
ECE 142 Circuits and Electronics II	3
ECE 193 Electrical & Computer Engineering Projects I	1.5
Ma 326 Linear Algebra	3
Humanities/Social Sciences Elective	3
Total Credits Fall Semester	19.5
Spring Semester:	
ECE 103 Communication Networks	3
ECE 135 Engineering Electromagnetics	4
ECE 194 Electrical & Computer Engineering Projects II	4
ECE 302 Probability Models & Stochastic Processes	3
Humanities/Social Sciences Elective	3
Total Credits Spring Semester	17

Senior Year	Credits
Fall Semester:	
ECE 195 Electrical & Computer Engineering Projects III	4
Non-technical Elective	3
Engineering or Science Electives	7
Total Credits Fall Semester	13
Spring Semester:	
ECE 196 Electrical & Computer Engineering Projects IV	3
Non-technical Elective	3
Engineering or Science Electives	8.5
Total Credits Spring Semester	14.5

Total credits required for degree **135**

Computer Engineering Track in Electrical Engineering

First Year	Credits
Fall Semester:	
ESC000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Introduction to Computer Science	3
HSS 1 Literary Forms and Experessions	3
Total Credits Fall Semester	18
Spring Semester:	
ESC000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ph 112 Physics I: Mechanics	4
ECE 150 Digital Logic Design	3
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
HSS 2 Texts and Contexts: Old Worlds and New	3
Total Credits Spring Semester	18.5

Sophomore Year	Credits
Fall Semester:	
ESC000.3 Professional Development Seminar	0
ECE 141 Circuits & Electronics I	3
ECE 161 Programming Languages	3
Ma 223 Vector Calculus	2
Ma 240 Ordinary and Partial Differential Equations	3
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Laboratory	1.5
HSS 3 The Making of Modern Society	3
Total Credits Fall Semester	19.5
Spring Semester:	
ESC000.4 Professional Development Seminar	0
ECE 110 MATLAB Seminar: Signals and Systems	0
ECE 111 Signal Processing & Systems Analysis	3
ECE 131 Solid State Materials	3
ECE 151 Computer Architecture	3
ECE 164 Data Structures and Algorithms I	2
Ma 224 Probability	2
Ph 214 Physics III: Modern Physics	3
HSS 4 The Modern Context: Figures and Topics	3
Total Credits Spring Semester	19

Junior Year	Credits
Fall Semester:	
ECE 101 Communication Theory	3
ECE 114 Digital Signal Processing	3
ECE 142 Circuits and Electronics II	3
ECE 165 Data Structures and Algorithms II	2
ECE 193 Electrical & Computer Engineering Projects I	1.5
Ma 352 Discrete Mathematics	3
Humanities/Social Sciences Elective	3
Total Credits Fall Semester	18.5
Spring Semester:	
ECE 103 Communication Networks	3
ECE 194 Electrical & Computer Engineering Projects II	4
ECE 302 Probability Models & Stochastic Processes	3
ECE 361 Software Engineering & Large System Design	3
Humanities/Social Sciences Elective	3
Total Credits Spring Semester	16

Senior Year	Credits
Fall Semester:	
ECE 195 Electrical & Computer Engineering Projects III	4
Non-technical Elective	3
Engineering or Science Electives	6
Total Credits Fall Semester	13
Spring Semester:	
ECE 196 Electrical & Computer Engineering Projects IV	3
Non-technical Elective	3
Engineering or Science Electives	6.5
Total Credits Spring Semester	12.5

Total credits required for degree **135**

MECHANICAL ENGINEERING DEPARTMENT AND PROGRAM

FACULTY

Baglione, Delagrammatikas, Lima, Sidebotham, Wei (chair), Wootton

MISSION STATEMENT

The Cooper Union's Department of Mechanical Engineering will produce broadly- and rigorously-educated graduates, able to practice professionally, pursue advanced studies and innovate in a wide range of fields. Together with our faculty and staff, our students will develop a commitment toward lifelong interdisciplinary learning, fulfill their potential for responsible leadership and inspire others to continuously pursue excellence by example.

Program Objectives

• Our graduates will apply their broad and rigorous education to responsible, interdisciplinary problem solving,

• communicate clearly and effectively in their chosen professions

• continue to learn and educate themselves in their fields of pursuit.

Program description

Mechanical engineering is concerned with the devices and phenomena related to the generation, transmission, application and control of power. Mechanical engineering grew up with the Industrial Revolution and is today the broadest of the engineering disciplines, encompassing many activities and fields of interest. Mechanical engineers may be involved with research and development, design, manufacturing, sales, application and service, administration and management, as well as teaching and consulting. Fields of interest include solid mechanics, materials, fluid mechanics, acoustics, heat transfer and thermodynamics, combustion, control systems, manufacturing, CAD/CAM and robotics or combinations of these as is often the case in the design and development work of complex projects. (Examples: the space shuttle, the investigation of alternate energy from renewable resources, the development of completely automated factories through robotics and human joint replacements.) At the Albert Nerken School of Engineering, the mechanical engineering faculty and students have been, and continue to be, involved in these and other exciting new developments through their project work, research work or consulting.

Mechanical engineering is an ideal foundation for careers in the aerospace industry, ocean engineering, marine engineering, biomedical engineering, the automobile industry, the power and utility industries and virtually any area of activity that requires analytical abilities combined with a strong background in design practice.

The sequences of courses shown in the undergraduate curriculum table emphasize the fundamental engineering sciences as well as their applications in a computer environment and professional design practice. By the selection of electives and of their design and research projects, students have a large degree of flexibility in exploring their own interests.

Graduate Program

Areas of research include computer-aided design and engineering, robotics, biomedical engineering, automotive systems, mechatronics, thermoelectric power generation, acoustics, combustion and other interdisciplinary areas of engineering.

Mechanical Engineering Program

Freshman Year	Credits
Fall Semester:	
ESC000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Introduction to Computer Science	3
HSS 1 Literary Forms and Expressions	3
Total Credits Fall Semester	18
Spring Semester:	
ESC000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ph 112 Physics I: Mechanics	4
EID 103 Principles of Design	3
or	
EID 110 Engineering Design Graphics	
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
HSS 2 Texts and Contexts: Old Worlds and New	3
Total Credits Spring Semester	18.5

Sophomore Year	Credits
Fall Semester:	
ESC000.3 Professional Development Seminar	0
Ma 223 Vector Calculus	2
Ma 224 Probability	2
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Laboratory	1.5
ESC 100 Engineering Mechanics	3
ESC 110 Materials Science	3
HSS 3 The Making of Modern Society	3
Total Credits Fall Semester	18.5
Spring Semester:	
ESC000.4 Professional Development Seminar	0
ESC 121 Basic Principles of Electrical Engineering	2
Ma 240 Ordinary and Partial Differential Equations	3
Ph 214 Physics III: Optics and Modern Physics	3
ESC 101 Mechanics of Materials	3
ESC 161 Systems Engineering	3
ME 155 Design and Prototyping	2
HSS 4 The Modern Context: Figures and Topics	3
Total Credits Spring Semester	19

Junior Year	Credits
Fall Semester:	
ESC 130 Engineering Thermodynamics	3
ESC 140 Fluid Mechanics & Flow Systems	3
ME 100 Stress and Applied Elasticity	3
ME 151 Feedback Control Systems	3
Engineering or Science Elective	3
Humanities/Social Sciences Elective	3
Total Credits Fall Semester	18
Spring Semester:	
ME 101 Mechanical Vibrations	3
ME 130 Advanced Thermodynamics	3
ME 142 Heat Transfer	3
ME 160 Engineering Experimentation	3
Engineering or Science Elective	3
Humanities/Social Sciences Elective	3
Total Credits Spring Semester	18

Senior Year	Credits
Fall Semester:	
ME 120 Design Elements	3
or	
ME 141 Fundamentals of Aerodynamics	
ME 163 Mechanical Engineering Projects	3
ME 312 Manufacturing Engineering	3
Free Electives	4
Total Credits Fall Semester	13
Spring Semester:	
ME 164 Capstone Senior Mechanical Engineering Design	3
ME 320 Mechanical Design	3
or	
ME 300 Space Dynamics	
Free Electives	6
Total Credits Spring Semester	12

Total credits required for degree **135**

BACHELOR OF SCIENCE IN ENGINEERING CURRICULUM

General Engineering

The School of Engineering offers a program in General Engineering leading to the degree of bachelor of science in engineering (B.S.E.). It Is Intended for students who have a clear Idea of their educational objectives. These may require a more flexible Interdisciplinary course of study. This program Is also suitable for students who desire a strong, broad-based, rigorous engineering background as preparation for graduate study in mathematics, science or other disciplines.

Curriculum

While details of programs will vary according to educational goals and advisor's requirements, the core is as follows:

	Credits
Core Courses	55
Humanities and Social Sciences (over and above the core courses)	minimum 6
Engineering and Engineering Sciences[1] (over and above the core courses)*	minimum 44
Free Electives[2]	30
Total credits	**135**

The program is administered by an interdepartmental committeee. Approximately 10 percent of the engineering undergraduates currently undertake this program.

Each student is assigned an adviser from the committeee; other faculty may also act as co-advisors. Choice of electives Is closely monitored for academic rigor and coherence by the interdepartmental committeee.

Students who are considering applying to medical or dental school after completing the program are advised to take one year of biology. Law schools may require additional courses in the social sciences.

The oprogram is not suitable for students who wish licensure.

[1] Courses with prefix BIO, ChE, CE, CS, EE/ECE, ME, EID, ESC

[2] Any course offered at The Cooper Union

Core Curriculum of the School of Engineering

Freshman Year	**Credits**
Fall Semester:	
ESC 000.1 Professional Development Seminar	0
Ma 110 Introduction to Linear Algebra	2
Ma 111 Calculus I	4
Ch 110 General Chemistry	3
EID 101 Engineering Design and Problem Solving	3
CS 102 Computer Programming for Engineers	3
HSS 1 Literary Forms and Expressions	3
Total credits fall semester	18
Spring Semester:	
ESC 000.2 Professional Development Seminar	0
Ma 113 Calculus II	4
Ch 111 General Chemistry Laboratory	1.5
Ch 160 Physical Principles of Chemistry	3
Ph 112 Physics I: Mechanics	4
HSS 2 Texts and Contexts: Old Worlds and New	3
Total credits spring semester	15.5

Sophomore Year	**Credits**
Fall Semester:	
ESC 000.3 Professional Development Seminar	0
Ma 223 Vector Calculus	2
Ma 224 Probability	2
Ph 213 Physics II: Electromagnetic Phenomena	4
Ph 291 Introductory Physics Lab	1.5
HSS 3 The Making of Modern Society	3
Electives	6
Total credits fall semester	18.5
Spring Semester:	
ESC 000.4 Professional Development Seminar	0
Ma 240 Ordinary and Partial Differential Equations	3
Ph 214 Physics III: Optics and Modern Physics	3
HSS 4 The Modern Context: Figures and Topics	3
Electives	10
Total credits spring semester	19

MASTER'S PROGRAM DEGREE REQUIREMENTS

For Cooper Union integrated bachelor/master's program students

Credit Requirements

A minimum of 30 credits beyond the baccalaureate degree must be completed at The Cooper Union (in addition to possible undergraduate deficiencies). Of these, not more than six credits may be undergraduate-level courses. The 30 credits offered for the degree must satisfy the following distribution:

	Credits
The major	**minimum 12**
A coherent concentration of graduate-level courses in the chosen field, which must include courses approved by the adviser(s). (A planned course of study must be submitted for approval by the dean's office.)	
The minor	**minimum 12**
A concentration in an area of engineering other than the chosen major.	
Thesis project	**65**
Total Credits	**30**

Grade Requirement

A minimum grade point average of 3.0 is needed in all courses to satisfy the master's degree requirement.

Appropriate Excess Credits Taken as an Undergraduate

For Cooper Union baccalaureate holders, any credits of appropriate level, taken as undergraduates in excess of their bachelor's degree requirement, may be applied to the master's degree, subject to the above requirements and advisory approval.

Time Limitation

The requirements for the master of engineering program must be completed within two years of admission except for extraordinary circumstances that require the express consent of the dean or associate dean of engineering. Requests for such extension must be presented in writing to the Office of the Dean in the final semester of the second year. Thesis adviser(s)'s approval is also required. Master's students who receive approval to extend their studies beyond two years will be assessed a maintenance of matriculation fee of $1,000 per semester.

Program of Study

A complete program of study, major as well as minor, is designed by the student with the assistance and approval of the academic adviser(s) and approved by the Office of the Dean of Engineering.

Minors

Minor concentrations are offered in accordance with faculty capabilities and school resources. Courses in engineering and science are chosen to form an innovative and coherent program of study for a minor with the approval of the department and faculty advisor(s).

Thesis/Project

• Each student is required to submit a thesis or project in the major or the minor area of study, equivalent to a maximum of six credits (400 level), for partial fulfillment of the master of engineering requirements. This project must be discussed with and approved by an adviser prior to being started.
• The thesis or project must be successfully defended orally by the student and submitted in written form.

Fellowships

One source of funding available to students wishing to pursue graduate study in engineering is the Enders Fund, governed by the will of Henry C. Enders and administered by the New York Community Trust. This fellowship is available to engineering graduates of The Cooper Union who plan to do graduate work in either chemistry, chemical engineering, chemistry-based environmental engineering or chemistry-based bioengineering and, who have satisfactorily completed all of the chemistry courses required of Cooper Union chemical engineering graduates. Recipients are selected by the joint faculties of chemistry and chemical engineering.

DEPARTMENTS

Chemistry

Faculty: Bové (chair), Newmark, Savizky, Topper

The Department of Chemistry offers a wide range of courses that are necessary for the understanding of the various engineering disciplines. First-year engineering students enroll in the following courses: General Chemistry (a general quantitative and descriptive overview of chemistry), Physical Principles of Chemistry (a quantitative discussion of chemical thermodynamics, electrochemistry and chemical kinetics) and General Chemistry Laboratory (chemical experimentation with emphasis on data recording, report writing and safety).

Sophomore and junior level courses required for chemical engineering majors can also be taken as electives by those wishing to further their knowledge in the environmental, biomedical, instrumental and physical areas.

In addition, elective courses, suitable for students interested in bioengineering or students intending to go to medical school, are available.

Research at the undergraduate and master's levels can be conducted under the supervision of the chemistry faculty.

Interested students should meet with the chemistry chair to discuss possible research areas.

The department operates laboratories in general chemistry, organic chemistry and instrumental analysis and for research projects.

Mathematics

Faculty: Agrawal (chair), Bailyn, Casti, Hopkins, Smyth, Vulakh
Visiting: Mintchev

The primary responsibility of the Department of Mathematics is the maintenance and delivery of the core mathematics curriculum for the School of Engineering. This consists of a sequence of required courses given in the first two years covering calculus, linear algebra, probability, vector calculus and differential equations. In addition to the core courses, there are a variety of elective mathematics courses, some of which are computer related. The mathematics curriculum will more than adequately prepare the student for professional work as well as graduate study in engineering and applied mathematics.

The faculty of mathematics strives to develop in the student a firm foundation in, and an appreciation of, the structure and methods of mathematics. Students interested in mathematics research should consult the chair for specific areas of expertise.

Mathematics Minor

The department of mathematics offers a minor in mathematics. Students seeking a minor in mathematics must complete at least 15 credits of mathemaitcs coursework in addition to the 17 credits required by every engineering department. These additional credits must includee Advanced Calculus I and II (Ma 350, 351), Linear Algebra (Ma 326), Modern Algebra (Ma 347) and an elective course in mathematics at or above the 300 level. An overall G.P.A., at graduation, of at least 3.0 among the mathematics portion (32 credits) of the program is required to obtain a minor in mathematics.

Physics

Faculty: A. Wolf (chair), Uglesich

The physics program at The Cooper Union provides a sequence of introductory courses devised to introduce students in engineering to fundamental physical concepts that underlie all the engineering disciplines. Additionally, the Physics Department offers elective courses that are crafted to provide an enhanced understanding of specially selected fields of interest in engineering science.

COURSE RENUMBERING

In the process of curriculum development, courses have been renumbered. This chart shows the new and old numbers for convenience. You may find an old number listed in the prerequisites for a course.

CS 102	EID102	Introduction to Computer Science
ECE 101	EE101	Communication Theory
ECE 103	EE103	Communications Networks
ECE 110	EE000.1	MATLAB seminar
ECE 114	EE114	Digital Signal Processing
ECE 116	EE211	Music & Engineering
ECE 121	EE171	Control Systems
ECE 131	ESC310	Solid State Materials
ECE 132	EE132	Electro-mechanical Energy Conversion
ECE 150	EE150	Digital Logic Design
ECE 151	EE151	Computer Architecture
ECE 161	EID151	Programming Languages
ECE 163	EE153	Data Structures
ECE 193	EE160	EE projects I
ECE 194	EE161	EE projects II
ECE 195	EE162	EE projects III
ECE 196	EE163	EE projects IV
ECE 301	EE301	Communications Systems
ECE 309	EE360	Intro to Cryptography
ECE 321	EE372	Control System Design
ECE 323	EE381	Embedded System Design
ECE 341	EE143	Integrated Circuit Engineering
ECE 343	EE391	Bio-instrumentation and Sensing
ECE 344	EID123	Bio-systems and Instrumentation
ECE 361	EE352	Software Engineering and Large Systems Design
ECE 399	EE399	Selected topics in Electrical Engineering
ECE 401	EE401	Selected Topics in Communication Theory
ECE 402	EE402	Selected Topics in Probability and Stochastic Processes
ECE 403	EE407	High-speed Networks
ECE 404	EE404	Communication Coding
ECE 405	EE405	Advanced Digital Communications
ECE 408	EE408	Wireless Communications
ECE 409	EE460	Advanced Cryptography
ECE 413	EE413	Robust Signal Processing
ECE 415	EE415	Wavelets & Multi-resolution Imaging
ECE 416	EE416	Adaptive Filters
ECE 417	EE417	DSP System Design
ECE 418	EE418	Digital Video
ECE 421	EE471	Advanced Control System Design
ECE 422	EE482	Selected Topics in Embedded Systems
ECE 423	EE464	Digital & Microprocessor Control
ECE 431	EE421	Microwave Engineering
ECE 433	EE406	Optical Communication Devices & Systems
ECE 441	EE414	Digital Integrated Circuit Engineerin
ECE 443	EE440	Thin Film Electronics
ECE 453	EE453	Advanced Computer Architecture
ECE 457	EE457	Computer Operating Systems
ECE 461	EE451	Advanced Programming Methods
ECE 462	EE452	Interactive Engineering Graphics
ECE 464	EE454	Databases
ECE 466	EE456	Compiling Techniques
ECE 468	EE458	Computer Vision
ECE 469	EE459	Artificial Intelligence
ECE 491	EE491	Selected Topics in Electrical & Computer Engineering
ECE 499	EE499	Master's Thesis

Chemical Engineering Courses

Undergraduate

ChE 121 Chemical Reaction Engineering After consideration of chemical reaction kinetics and thermodynamics, the course focuses on the design relationships for batch, semi-batch, plug-flow and mixed reactors. The application of these design relationships is explored in ideal, isothermal, non-isothermal, adiabatic reactors. Homogeneous, heterogeneous and biological systems are discussed including the effect of transport phenomena on reaction rates and reactor design.
3 credits. Prerequisites: ESC 170 and ESC 140

ChE 131 Advanced Chemical Engineering Thermodynamics
Concept of fugacity in imperfect gases; chemical potential and partial molal properties in mixtures; Gibbs-Duhem Equation; ideal solutions of imperfect gas mixtures; the Lewis and Randall Rule; methods of calculating activity coefficients in non-ideal mixtures; vapor-liquid equilibria; checking thermodynamic consistency of vapor-liquid equilibrium data; equilibrium constant, enthalpy change and Gibbs free energy of formation in chemical reactions.
3 credits. Prerequisite: ESC 130.1

ChE 141 Heat Transmission
Thermal conductivity; steady state conduction in solids and heterogeneous materials; transient conduction; convective heat transfer; heat transfer during boiling and during condensation; design of heat-exchange equipment; radiation heat transfer.
3 credits. Prerequisite: ESC 140

ChE 142 Mass Transfer Operations
Diffusion mechanisms and phenomena; estimation of diffusivity. Fick's law of diffusion; concentration distributions in solid and fluid flow with or without chemical reaction. Application of thermodynamic and transport concepts to the design of continuous-contact and staged mass transfer processes. Distillation, gas absorption and drying. Examination of the limitations of theory and empiricism in design practice.
4 credits Prerequisites: ChE 131, ChE 141 and ESC 140

ChE 151 Process Simulation and Mathematical Techniques for Chemical Engineers In this course computer-aided design is applied to chemical engineering problems in fluid flow, heat transfer, mass transfer and chemical reactor analysis. Topics include: matrices and determinants properties and special matrices, systems of linear equations and methods of solution by matrices, eigenvalues, eigenvectors and applications to least squares and stage processes. Steady and unsteady general diffusion equation, one- and two-dimensional heat transfer equation, Fourier series, Laplace and Z transforms and applications. Series and numerical solutions, Power, Bessel, Euler, Runge-Kutta, Milne, Finite differences approximations and Crank-Nicholson. Applications.
3 credits

ChE 152 Chemical Process Dynamics and Control Introduction to logic of process dynamics and principles of control in chemical engineering applications; block diagram notation, input disturbance, frequency response and stability criteria for chemical equipment and chemical reaction systems; single- and multiple-loop systems; phase plane analysis of reaction systems; application of analog computer in solution of problems.
3 credits. Prerequisite: ChE 151

ChE 161.1 Process Evaluation and Design I The course uses design projects to explore process flow diagrams and initial equipment design estimates based on process and unit operation material and heat balances. Studies include equipment cost estimation methods that are developed into process economic evaluations and profitability analysis. The course concludes with process and equipment design using Simulation Science's PRO-vision/PRO-II and an examination of optimization techniques.
3 credits each. Prerequisites: ChE 141 and ChE 121

ChE 161.2 Process Evaluation and Design II This is a continuation of ChE 161.1, and is the "capstone design course" in chemical engineering. All aspects of chemical engineering are integrated in the design of a chemical process plant. The design process consists of flow-sheet development, equipment selection and sizing, utility requirements, instrumentation and control, economic analysis and formulation of safety procedures. The plant design is carried out in class and includes the use of professional simulation packages. The AIChE project is included in this course.
3 credits. Prerequisite: ChE 161.1

ChE 162.1-162.2 Chemical Engineering Laboratory I & II
This laboratory course emphasizes the application of fundamentals and engineering to processing and unit operations. The experiments range from traditional engineering applications to new technologies and are designed to provide hands-on experiences that complement the theories and principles discussed in the classroom. Preparation of detailed project reports and oral presentations are important components of this course.
1.5 credits each. Prerequisite: ChE 121, ChE 141; co-requisite: ChE 142

ChE 311 Introduction to Polymer Technology Introduction to the chemistry and physical status of polymer materials. Discussion on formation of polymers from corresponding monomers, emphasizing mechanisms and kinetics of various polymerization techniques. Measurements of average molecular weights and molecular weight distribution of polymers. Viscosity and rheology of polymer solutions and melts.
3 credits

ChE 321 Chemical Reactor Design
Design and analysis of chemical reactor systems; transport phenomena; reactor dynamics; design optimization; experimental techniques.
3 credits. Prerequisite: ChE 121

ChE 340 Industrial Waste Treatment
This course deals with the treatment of industrial waste streams. Topics include: sources of wastewater, characterization of industrial wastewater, BOD, COD, TOC, The OD, primary treatment by physical unit operations (coagulation and flocculation, sedimentation, flotation, thickeners, filtration, absorption,…), secondary treatment by unit processes (ion exchange, chlorination, de-chlorination,…); biological treatments (kinetics and reactor design, aerobic, anaerobic,…); industrial applications and municipal and government regulations. This course is 50 percent engineering science, 50 percent engineering design. The course also includes a research paper on an environmental topic.
3 credits. Prerequisite: Ch 160

ChE 342 Separation Processes
Advanced study of the theory and design of multi-component distillation, gas absorption and extraction operations. Thermal diffusion, foam fractionation, parametric pumping, reverse osmosis and chromatographic separations are examples of less conventional operations discussed. Thermodynamics of phase-equilibrium; diffusion and low- and high-flux mass transport theory.
3 credits. Prerequisite: ChE 151

ChE 391 Research Problem I
An elective course available to qualified and interested students recommended by the faculty. Students may select problems of particular interest in some aspect of theoretical or applied chemical engineering. Topics range from highly theoretical to completely practical, and each student is encouraged to do creative work on his or her own with faculty guidance.
3 credits. Prerequisite: senior standing.

ChE 392 Research Problem II Continuation of ChE 391.
3 credits. Prerequisite: ChE 391

ChE 393 Research Problem 111 Continuation of ChE 392.
3 credits. Prerequisite: ChE 392

ChE 394 Research Problem IV Continuation of ChE 393.
3 credits. Prerequisite: ChE 393

Graduate

ChE 411 Polymer Technology and Engineering Structures and synthesis of Carbon-Carbon and heterogeneous chain polymers, mechanisms and kinetics of emulsion, condensation, ionic stereo-specific polymerizations. Rubber elasticity. Rheological and viscoelastic properties of polymers and polymer solutions. Survey and investigations of advanced topics are required.
3 credits. Prerequisite: permission of instructor

ChE 421 Advanced Chemical Reaction Engineering
Principles and practices of chemical reaction systems emphasizing heterogeneous chemical kinetics, coupled heat and mass transfer in reacting systems and reactor dynamics. Modeling and simulation of systems are extensively applied.
3 credits. Prerequisite: ChE 121

ChE 430 Thermodynamics of Special Systems (same as EID and ME 430)
3 credits. Prerequisite: ChE 131

ChE 431 Advanced Chemical Engineering Thermodynamics and Molecular Theory
Modern methods of applying thermodynamics and molecular physics to phase behavior of fluid mixtures, intermolecular forces and thermodynamic properties, molecular dynamic properties, molecular theory of gases and liquids, theories of liquid solutions and fluid mixtures at high pressures.
3 credits. Prerequisite: ChE 131

ChE 434 Special Topics in Combustion (same as ME 434)
3 credits. Prerequisite: ME334 or permission of instructor

ChE 435 Transport Processes in Internal Combustion Engines (same as ME 435).
3 credits. Prerequisite: permission of instructor

ChE 440 Advanced Fluid Mechanics (same as EID and ME 440).
3 credits. Prerequisites: ESC 140 and permission of instructor

ChE 441 Advanced Heat and Mass Transfer (same as EID 441).
3 credits. Prerequisite: ESC 141

ChE 442 Multi-Component Distillation Various methods for vapor-liquid equilibrium calculations, including the Wilson parameter approach, are reviewed. Distillation tower design based on steady-state approach includes analytical method using matrix operation and various convergence methods are discussed in detail. Introduction to unsteady-state approach for tower design and dynamics evaluation. Students are encouraged to apply existing techniques to complex towers and to improve the state of the art.
3 credits. Prerequisite: ChE 142

ChE 444 Boundary Layer Theory
Study of heat, mass and momentum transfer in the boundary layer region of a submerged body; emphasis on continuum fluid systems, with introduction to rarified and non-continuum gaseous systems; analytical, numerical and analog methods of solutions.
3 credits. Prerequisite: ESC 141

ChE 451 Digital Simulation
Principles of digital simulation for chemical processes and other engineering problems are introduced. Groups of subroutines as essential tools for dynamic simulation and evaluation are developed. Projects involving advanced dynamic simulations of chemical engineering systems are required.
3 credits. Prerequisite: permission of instructor

ChE 452 Chemical Process Optimization Various algorithms of optimization techniques are introduced. Methods covered include both analytical and numerical approaches. Applications to optimal reactor design. Optimal control of chemical process equipment performance is demonstrated. Solution by students of assigned optimization problems in chemical engineering on digital or analog computers is required.
3 credits. Prerequisite: ChE 451

ChE 453 Digital Computer Process Control An introductory course in digital computer control. Topics discussed include basic mathematics of sampling data systems; control algorithms using transformation, direct digital control, supervisory control, application of the digital computer to advanced control and optimal control. Analog to digital and digital to analog conversions, acquisition of laboratory data and remote control of experimental equipment are also covered.
3 credits. Prerequisite: ChE 152

ChE 454 Advanced Experimental Process Control Advanced experimental process control concepts and advanced digital computer control. Three-mode feed forward control of process variables including temperature, pressure, level and pH value. Feed forward, proportional and cascade controls of various process variables. Logic programmable control. Series communication control. Computer controls step change, single-in, single-out and transfer function evaluation. Computer data acquisition.
3 credits. Prerequisite: ChE 152

ChE 460 Chemical Engineering Equipment Design The chemical engineer must develop, design and engineer both the complete process and the equipment used; choose the proper raw materials; operate the plant efficiently, safely and economically; and see to it that products meet the requirements set by the customer. Chemical engineering is both an art and a science. Whenever science helps the engineer to solve a problem, science should be used. When, as usually the case, science does not give a complete answer, it is necessary to use experience and judgement. The professional stature of an engineer depends on skill in utilizing all sources of information to reach practical solutions to processing problems. This course will concentrate specifically on the theoretical and practical principles of detailed equipment design for mass transfer, heat transfer and reaction operations. Attempts will be made to emphasize modern technologies used in these operations. Equipment covered will vary from year to year.
3 credits

ChE 490 Process Synthesis
This course provides a new basis for the design of integrated chemical processes. The ability to predict, at the outset, achievable design targets that have a sound scientific basis is fundamental to the approach. These targets relate to energy, capital and raw materials, costs and flexibility. Topics will include review of basic thermodynamic concepts, capital/energy trade-off, process integration–multiple utilities, process/utility interface, reactors and separators in the context of overall process–power optimization, design for flexibility, total sites layout, batch processes and process plant retrofit.
3 credits. Prerequisites: ChE 161.1 and ChE 161.2 or permission of instructor

ChE 499 Thesis/Project
Master's candidates are required to conduct, under the guidance of a faculty adviser, an original investigation of a problem in chemical engineering, individually or in a group, and to submit a written thesis describing the results of the work.
6 credits for full year

Civil Engineering Courses

Undergraduate

CE 120 Civil Engineering Fundamentals Planning, execution and interpretation of drawings and specifications for civil engineering projects. Sample drawings and specifications. Contractual requirements. Sample contracts. Permitting, scheduling and cost estimation. Basic operations of design and construction firms. Interface with other disciplines on civil engineering projects.
3 credits. Prerequisite: EID 101

CE 121 Structural Engineering I
Discussion of materials, loads and forms of structures. Analysis of determinate structures. Displacements of structures and their importance in applications. Experimental aspects of materials behavior in structural applications. Emphasis is placed on basic experimental techniques, design of experiments, selection and use of appropriate instrumentation and interpretation of results.
4.5 credits (3 hours of lecture, 3 hours of laboratory).
Prerequisite: ESC 101

CE 122 Structural Engineering II
Modern methods of structural analysis of indeterminate structures. Discussion of energy methods, force methods and displacement methods. Formulation of elementary matrix stiffness and flexibility methods. Computer applications in structural analysis.
3 credits. Prerequisite: CE 121

CE 131 Introduction to Geotechnical Engineering
Introduction to various indexing tests of soils, clay mineralogy, permeability, seepage and flow nets, stress distribution in soil masses, one-dimensional consolidation theory, strength characteristics of soils, application of Mohr's Circle to soil mechanics, stability of slopes.
4.5 credits (3 hours of lecture, 3 hours of laboratory). Prerequisite: ESC 101; prerequisite or co-requisite. ESC 140

CE 141 Environmental Systems Engineering Qualitative and quantitative treatment of water and wastewater systems as related to domestic and industrial needs and their effect on the environment. Introduction to air pollution sources and control and solid/hazardous waste engineering. Design of water and wastewater treatment plants. Field and laboratory techniques for measurement of water quality parameters. Laboratory analysis of representative waters and wastewaters for commonly determined parameters as related to applications in water environment.
4.5 credits (3 hours of lecture, 3 hours of laboratory). Prerequisite: ESC 140

CE 142 Water Resources Engineering (same as EID 142)
Problems in conservation and utilization of water. Hydrologic techniques. Surface water and ground water supplies. Water transmission and distribution. Flood control, navigation and irrigation. Introduction to open channel flow and pipe networks. Design of hydraulic structures. Experimental aspects of hydraulic phenomenon. Emphasis is placed on basic experimental techniques, design of experiments, selection and use of appropriate instrumentation and interpretation of results.
4.5 credits (3 hours of lecture, 3 hours of laboratory). Prerequisite: ESC 140

CE 331 Foundation Engineering
Layout of subsurface investigation program, SPT (Standard Penetration Test), Dutch-cone penetrometer. Analysis and design of spread footings on cohesive and cohesionless soil by stability and settlement procedures, combined footings, strap footings, floating foundations and pile foundations. Settlement analysis due to deep-seated consolidation.
3 credits. Prerequisite: CE 131

CE 332 Lateral Earth Pressures and Retaining Structures
Introduction to classical lateral earth pressure theories (Rankine and Coulomb). Analysis and design of cantilever and gravity retaining walls, cantilevered and anchored sheetpile bulkheads, anchorage systems (individual and continuous deadmen, grouted tiebacks) and braced cofferdams. Gravity Wall Systems (Gabion Walls, Criblock Walls and Double Wall).
3 credits. Prerequisite: CE 131

CE 341 Design of Steel Structures
Study of behavior and design of structural steel components and their connections. Understanding and development of design requirements for safety and serviceability, as related to latest structural steel specifications by the American Institute of Steel Construction (A.I.S.C.). Current design emphasizing LRFD, fabrication and construction practices. Composite design.
3 credits. Prerequisite: CE 121; co-requisite: CE 122

CE 342 Design of Reinforced Concrete Structures Study of the behavior and design of structural concrete components and their connections. Understanding and development of design requirements for safety and serviceability, as related to latest specifications by the American Concrete Institute (A.C.I.). Current design, fabrication and construction practices. Introduction to prestressed concrete.
3 credits. Prerequisite: CE 122

CE 346 Hydraulic Engineering
An integration and application of the principles of fluid mechanics to problems concerned with water supply and distribution. Open channel flow and design of hydraulic structures.
3 credits. Prerequisite: CE 142

CE 351 Urban Transportation Planning Historical background and evolution of current procedures used in the "urban transportation planning process." Covered are the historical framework, urban development theories, land use, trip generation, trip distribution models, traffic assignment techniques, modal split and introduction to urban transportation systems.
3 credits

CE 352 Elements of Transportation Design Review of urban transportation planning process. Specific design elements of various highway and public transportation systems. Included are locational design, traffic service, environmental impact analyses, alternatives evaluation, geometric design elements, operations and capacity and level-of-service analysis. Also, selected topics in urban transportation systems.
3 credits

CE 361 Civil Engineering Experimental Projects
Exploratory experimental projects in materials, hydraulics, soils, environmental or other civil engineering specialties. Projects are conceived, designed and executed by groups of students under faculty supervision.
2 credits. Prerequisite: Permission of instructor. (Students are required to have taken introductory civil engineering subject(s) related to project)

CE 363 Civil Engineering Design I
Individual or group design projects based upon the interests of the students and with the approval of the instructor. Final engineering reports and formal oral presentations are required for all projects. Lectures by faculty and professional practitioners cover the following topics: engineering, environmental and economic feasibility assessment issues; preparation of plans and specifications; cost estimates; progress chart and critical path; interfacing with community; etc. Field visits to major New York City projects under construction.
3 credits. Prerequisite: permission of instructor. (Students are required to have taken introductory CE subject(s)) related to project)

CE 364 Civil Engineering Design II Continuation of CE 363.
3 credits. Prerequisite: CE 363

CE 369 Civil Engineering Project
Individual design, research or experimental projects. Open only to well-qualified students.
3 credits. Prerequisite: permission of instructor

CE 380 Fundamentals of Construction Management (same as EID 380)
3 credits

CE/EID 390 Introduction to Sustainable Design Sustainable design minimizes the impact on the environment by site planning and design, energy and water conservation and interior environmental quality. This course will focus on the design of a prototype structure using sun, light, air, renewable materials, geological systems, hydrological systems and green roofing. Each student will develop a project outlined by the U.S. Green Building Council rating system known as LEED. The six areas that will be developed to design the project are: sustainable sites, water efficiency, energy and atmosphere, material and resources, indoor environmental quality and innovative design process. Class time is separated into a series of lectures, private consultations and student presentations.
3 credits. Prerequisite: permission of instructor and ESC 140; CE 122 or ME 100

Graduate

CE 411 Introduction to Civil Engineering Management
Overview of the civil engineering profession and the importance of infrastructure to society. The course will emphasize the planning, design, construction and maintenance of public works. New York City will serve as the laboratory for field visits and course projects.
3 credits. Prerequisite: permission of instructor

CE 412 Stochastic Concepts in Civil Engineering
Introduction to probabilistic methods and stochastic concepts in civil engineering. Elements of applied probability and statistics. Engineering applications involving economic decisions under uncertainty. Realistic and common civil engineering examples and problems in transportation, structures, materials, soils and water resources.
3 credits. Prerequisites: Ma 224 and Ma 240

CE 414 Solid Waste Management
Engineering aspects of solid waste collection, transport and disposal, including sanitary landfill design, incineration, composting, recovery and re-utilization of resources. Optimization techniques of facility-siting and collection route selection and economic evaluation of factors affecting selection of disposal methods.
3 credits. Prerequisite: permission of instructor

CE 421 Matrix Methods of Structural Analysis In-depth treatment of matrix methods. Application to linear as well as nonlinear analysis of plane and space structures. Discussion of current techniques. Computer applications.
3 credits. Prerequisites: CE 122, Ma 240

CE 422 Finite Element Methods (same as EID 422)
Shape functions and generalized displacements. Assemblage of elements. Convergence criteria. Triangular, rectangular and quadrilateral elements in plane stress and plane strain. Isoparametric formulations. General solids. Hexahedral and tetrahedral elements. Flexure in plates. General shells. Natural coordinates. Computer programs.
3 credits. Prerequisite: CE 122 or ME 100

CE 424 Plates and Shells
Discretized grid-work and grillage analysis by matrix techniques. Development of the classical thin plate theory. Mathematical and numerical solutions of the plate equation. Introduction to thin shell theory. Practical applications such as cylindrical shell roofs, spherical shell with an edge ring and various cases of shells of revolution.
3 credits. Prerequisite: CE 122

CE 425/EID 425 Structural Dynamics Dynamic behavior and design of structures subjected to time-dependent loads. Included in the load systems are earthquakes, blasts, wind and vehicles. Shock spectra and pressure impulse curves. Special applications in blast mitigation design.
3 credits. Prerequisite: CE 122

CE 426 Advanced Structural Design
Discussion of principal design codes (AISC, ACI and AASHTO) as they relate to ASCE Standards, the International Building Code (IAC) and NYC Building codes Advanced materials behavior. Strength and serviceability requirements. Design of composite girders and slabs. Limit state response and formation of plastic hinges in steel and concrete structures. Structural upgrade and retrofit of existing structures.
3 credits. Prerequisite or co-requisite: CE 341

CE 427 Behavior and Design of Prestressed Concrete Structures
Behavior and design of prestressed members in flexure, shear, bond and torsion; continuous beams; columns; prestressed systems; loss of prestress. Emphasis is placed on ultimate strength design and the background of latest ACI code.
3 credits. Prerequisite: CE 341

CE 428 Plastic Analysis and Design
Limit analysis of beams and frames. Upper and lower bound theorems. Collapse loads and displacements. Applications to steel and concrete structures. Special applications in blast mitigation design.
3 credits. Prerequisite: CE 341

CE 431 Advanced Foundation Engineering Analysis and design of foundations subjected to vibratory loading, beams on elastic foundation (vertical subgrade modulus), laterally loaded piles (with software applications), Wave Equation Analysis of Piles (with software application of WEAP).
3 credits. Prerequisites: CE 131 and permission of instructor

CE 432 Special Topics in Lateral Earth Pressure and Retaining Structures Analysis and design of cellular cofferdams, reinforced earth-retaining structures, slurry walls and retaining structures subjected to earthquake loading, soil nailing.
3 credits. Prerequisites: CE 131 and permission of instructor

CE 433 Advanced Topics in Geotechnical Engineering I
Analysis of slopes using translatory slides and available software packages (PCSTABL). Ground improvement technologies: including dynamic compaction, grouting, ground freezing and reinforced earth technologies.
3 credits. Prerequisite: permission of instructor

CE 434 Advanced Topics in Geotechnical Engineering II
Stresses in homogeneous and layered systems due to surface and buried loads. Development of flow network concepts and the Terzaghi one-dimensional consolidation theory, secondary consolidation, site pre-loading, sand drains and prefabricated vertical drains.
3 credits. Prerequisite: permission of instructor

CE 435 GeoEnvironmental Engineering (same as EID 435)
3 credits. Prerequisites: ESC 140, CE 141, CE 131 and permission of instructor

CE 440 Industrial Waste Treatment Design Integrated lecture and design periods that cover the sources of industrial wastewaters, their quantities and characteristics, and their treatability by physical, chemical and biological processes. Status of regulations involving categorical standards, local and state industrial pretreatment programs, NPDES permits, etc. Problems and solutions involved in combining municipal and industrial waste treatment. Case studies.
3 credits. Prerequisite: permission of instructor

CE 441 Water and Wastewater Technology Wastewater sources and estimates of domestic, commercial and industrial flows. Integrated lecture and design periods that cover unit processes for water and wastewater treatment. Design projects include hydraulic and process design of oxidation ponds, screening, grit removal, sedimentation tanks, secondary biological treatment, other physicochemical processes and outfall design.
3 credits. Prerequisite: permission of instructor

CE 442 Open Channel Hydraulics
Derivation of the general one-dimensional equations of continuity, momentum and energy used in open channel flow analysis. Steady uniform flow and boundary resistance. Steady nonuniform flows, channel transitions and controls, hydraulic jumps, surges, surface curves for gradually varied flow including the effects of lateral inflow. Unsteady flow in open channels. Dynamic waves, method of characteristics, surge formation. Kinematic waves, flood routing and overland flow. Design of channels and other hydraulic structures.
3 credits. Prerequisite: CE 142

CE 443 Groundwater Hydrology
Physical process of flow in homogeneous and heterogeneous media. Development of governing equations and boundary conditions, analysis by analytical and numerical techniques. Groundwater resources; design of wells and prediction of yield. Analyses of transport of contaminants using deterministic and stochastic methods.
3 credits. Prerequisite: CE 142

CE 444 Hydrology
Hydrology of the water cycle related to air mass movement, precipitations, evaporation, stream flow, floods, infiltration and groundwater including statistical hydrology. Design of irrigation systems.
3 credits. Prerequisite: CE 142

CE 445 Coastal Engineering
Introduction of the hydrodynamics of waves in deep and shallow water Emphasis on physical interpretation of the results and their engineering application. Wave refraction, diffraction, storm surges and statistical aspects of water waves.
3 credits. Prerequisite: CE 142

CE 446 Pollution Prevention or Minimization Introduction to the new concept and regulations in the U.S. and Canada of Pollution Prevention or Waste Minimization for managing hazardous pollution and protecting the environment and public health. Methodology of conducting environmental audits and lessons learned from successful pollution prevention programs. Case studies of various programs in industry, etc.
3 credits. Prerequisite: permission of instructor

CE 447 Stream and Estuary Pollution Application of basic concepts of fluid kinetics and dynamics to the analysis of dispersal and decay of contaminants introduced into lakes, streams, estuaries and oceans. Analysis and modeling of leachate and other contaminants into groundwater.
3 credits. Prerequisite: CE 142

CE 448 Environmental and Sanitary Engineering (same as EID 448)
Topics include types of environmental pollution and their effects; water quality standards and introduction to laboratory analyses of water quality parameters; sources and estimates of water and wastewater flows; physicochemical unit treatment processes. Integrated lecture and design periods cover water supply network, wastewater collection system and water treatment design projects.
3 credits. Prerequisite: permission of instructor

CE 449 Hazardous Waste Management Definition and characteristics of hazardous wastes. Generation, transport, treatment, storage and disposal of hazardous wastes. Leachate characteristics and management. Treatment technologies. Monitoring and safety considerations. Obligations under Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Field trips.
3 credits. Prerequisite: permission of instructor

CE 450 Civil Engineering Construction Preparation of plans and specifications. The bidding and award process. Contractual relations between the owner and the contractor. Preparation of cost estimate for a competitively bid project. Preparation of a progress chart and critical path. Sequencing various job elements. Engineering the actual construction. Management of labor. Interlacing with the community. Environmental requirements. Job safety. Changes and unanticipated conditions. Contract disputes and their resolutions.
3 credits. Prerequisite: CE 341

CE 470 Urban Security
Design of urban systems to protect against terrorism. Analysis of blast loads. Blast mitigation design considerations. Technology transfer: military/defense to civilian sector. Response spectra. Pressure-Impulse Curves. Stand off distances. Blast mitigation measures for buildings, bridges and tunnels. Prevention of progressive collapse in tall buildings. Design of glazing. Retrofit upgrade of existing urban infrastructure. Proposed changes in New York City Building Code to protect against terrorism. Insurance issues for commercial buildings.
3 credits. Prerequisites: CE 122 or ME 101 and permission of instructor

CE 499 Thesis/Project
Master's candidates are required to conduct, under the guidance of a faculty adviser, an original investigation of a problem in civil engineering, individually or in a group, and to submit a written thesis describing the results of the work.
6 credits for full year

Electrical Engineering

Electrical and Computer Engineering (ECE)

Undergraduate

ECE 101 Communication Theory (formerly EE 101)
Information theory: entropy, information, channel capacity, rate-distortion functions, theoretical limits to data transmission and compression. Error control coding: block, cyclic and convolutional codes, Viterbi algorithm. Baseband and bandpass signals, signal constellations, noise and channel models. Analog and digital modulation formats (amplitude, phase and frequency), MAP and ML receivers, ISI and equalization. Coherent and non-coherent detection, carrier recovery and synchronization. Performance: computation of SNR, BER, power and bandwidth requirements. TDMA, FDMA, CDMA.
3 credits. Prerequisites: Ma 224 and ECE 111

ECE 103 Communication Networks (formerly EE 303) Analysis and design of communication networks. Network protocols, architecture, security, privacy, routing and congestion control, internet, local area networks, wireless networks, multimedia services. Physical layer, multiple access techniques, transport layer. Introduction to probabilistic and stochastic analytic techniques for communication networks. Simulation techniques.
3 credits. Prerequisites: ECE 150 and Ma 224

ECE 110 MATLAB Seminar: Signals & Systems A weekly hands-on, interactive seminar that introduces students to MATLAB, in general, and the Signal Processing Toolbox in particular. Students explore scientific computation and scientific visualization with MATLAB. Concepts of signal processing and system analysis that are presented in ECE111 or other introductory courses on the subject are reinforced through a variety of demonstrations and exercises. It is strongly encouraged for students taking a first course in signals and systems, or for students expecting to use MATLAB in projects or courses.
0 credits. 1 hour per week

ECE 111 Signal Processing & Systems Analysis
A presentation of signals and systems that does not rely on prior knowledge of electrical circuits or differential equations. Sine waves, phasors, continuous-time and discrete-time signals, sampling. Starting from elementary discrete-time systems (FIR filters), and moving on to more complex systems (IIR digital filters and analog filters), concepts such as impulse response, convolution, frequency response, transfer functions (z-transform and Laplace transform) are presented. Block and signal-flow diagrams. Linearity, causality, time-invariance, stability. Feedback: open-loop and closed-loop gain. Transient response, poles and zeros. Vector spaces of signals, Fourier analysis, modulated signals, random signals. Examples include speech and audio signals, communication and control systems. Extensive use of MATLAB.
3 credits. Prerequisite: Ma 113, co-requisite: ECE 110

ECE 114 Digital Signal Processing (formerly EE 114)
Review of Laplace and z-transforms. Minimum-phase and all-pass functions. Multidimensional signals, systems and Fourier analysis. Analog filter design, digital IIR and FIR filter design. Sampling, multirate systems and filter banks, A/D and D/A converter models. Discrete-time state-space. Filter structures, quantization effects and design to mitigate quantization effects. DFT and FFT. Spectral analysis of deterministic and random signals. Introduction to adaptive filters. Differential coding, transform coding. Speech, audio and video signals. Extensive use of MATLAB.
3 credits. Prerequisites: Ma 240 and ECE 111

ECE 121 Control Systems (formerly EE 171) Block and signal-flow diagrams, Mason's theorem. Laplace transform, frequency response, Bode plots, root locus, Routh-Hurwitz array. Analysis of feedback control systems: open-loop and closed-loop gain, Nichols chart, Nyquist diagram, gain and phase margin. Continuous-time state-space analysis, state-variable feedback, canonical forms, observability and controllability. Second-order models, transient and steady-state performance. Emphasis on analog systems, although digital control systems will be discussed as time allows. Extensive use of MATLAB.
3 credits. Prerequisites: Ma 240 and ECE 111

ECE 131 Solid-State Materials
Applied solid-state physics with emphasis on semiconductor materials. Crystals, quantum mechanics, Schrodinger equation, energy bands, Fermi-Dirac statistics, Fermi levels. Semiconductor physics: electrons and holes, doping, diffusion and drift, generation- recombination, mobility. Physics of PN junction and BJT; depletion, carrier injection, minority carrier profiles, Ebers-Moll equations, junction capacitance, hybrid-pi model. Breakdown, metal-semiconductor contacts, heterojunctions, fabrication techniques, temperature effects and additional topics as time allows. Diode circuits; DC analysis of BJTs in active, saturated and cutoff modes; single transistor amplifiers and small-signal models.
3 credits. Prerequisite: ECE141

ECE 132 Electro-Mechanical Energy Conversion (formerly EE 132) Analysis of energy sources and energy converters. Principles of electro-mechanical energy conversion; singly and multiply excited systems; rotating and linear machines; three-phase circuits; magnetic circuits and transformers; torque and induced voltage from field considerations; synchronous machines; induction motors; DC machines. Introduction to power electronics. Applications including high-speed transportation, energy storage and interconnection of distant generating stations.
3 credits. Prerequisites: ESC120 or ECE 141 and Ph 213

ECE 135 Engineering Electromagnetics
This course emphasizes time-varying fields, with topics presented from electrostatics and magnetostatics as necessary. Maxwell's equations, constitutive relations, phasor vector fields, wave and Helmholtz equations, potentials, boundary conditions. Plane waves in lossless and lossy materials, polarization, incidence. Transmission lines: transient analysis, TDR, phasor analysis, standing wave diagrams, Smith chart, impedance matching. Guided waves: TEM, TE and TM modes, dispersion, evanescence, cavity resonators. Microwave network analysis and device characterization with scattering parameters. Antennas, antenna arrays and Fourier optics. Additional topics from microwaves and optics will be covered as time allows. Students use a vector network analyzer to perform measurements at high frequencies.
4 credits. Prerequisites: Ma 223, Ph 213 and ECE 111

ECE 141 Circuits & Electronics I
Circuit analysis: KVL, KCL, loop and nodal analysis, systematic and "shortcut" solution methods. Transient analysis of first, second and higher order RLC circuits, initial conditions. Introduction to diode and transistor models and circuits.
3 credits. Prerequisite: Ma 113

ECE 142 Circuits & Electronic II
MOS circuits: DC operation and analysis. Single stage MOS amplifiers, circuit design, DC and small signal analysis. Cascode amplifier. Current mirrors, active loads. BJT and MOS differential amplifiers. Monolithic operational amplifiers. Output stages. Frequency response. Introduction to feedback theory, amplifier topologies. Circuit design and analysis are supplemented with industry standard CAD software.
3 credits. Prerequisites: ECE131, ECE141

ECE 150 Digital Logic Design (formerly EE 150)
Theoretical and practical issues concerning design with combinational and sequential logic circuits, and programmable logic devices. Number systems, Boolean algebra, representation and simplification of Boolean functions, universal logic families. Finite-state machines, state tables and state diagrams, flip-flops, counters, registers. Adders, decoders, comparators, multiplexers, memories and applications. Programmable devices: PLA, PLD, etc. Principles of analog circuits are presented in the context of real world problems, such as "glitches," power and ground bounce, contact bounce, tri-state logic and bus interfacing, timing circuits, asynchronous versus synchronous circuit components. Characterization of electronic and logical properties of digital circuits. Course work involves individual and team projects in which: digital circuits are designed and prototypes are constructed and tested on breadboards; designs involving programmable logic devices are developed using CAD tools. The projects, approximately 50 percent of the course grade, are used to assess technical writing, oral presentation, teamwork and project management skills.
3 credits. Prerequisites: none. Non-refundable materials fee: $40

ECE 151 Computer Architecture (formerly EE 151)
Basic structure of computers based on the von Neumann model. Generic one-bus, two-bus and three-bus architectures. Stack based design. Tri-state logic and interfacing to a bus. Aspects of bus timing and maximum running speeds. Instruction sets: 1, 1½, 2, 3 and more operand instructions. Operand addressing modes including case studies. Computer subsystems: (a) memory: dynamic and static RAM, refresh cycles, asynchronous data transfers; (b) I/O: interrupts vs. polling, ISRs and program controlled I/O. The control unit: microprogramming vs. hardwired controllers. Horizontal vs. vertical microinstructions. The execution of a program; instruction fetch and execution sequences; PC, IR and other special registers. Computer peripherals and secondary storage. Course work involves the building of advanced digital circuits using VLSI programmable chips provided in a kit of parts. Introduction to parallel and pipelined architectures
3 credits. Prerequisite: ECE 150. Non-refundable materials fee: $40

ECE 161 Programming Languages
Practical programming languages including C, C++ and Java; optionally Perl or additional languages. Memory, strings, pointers and arrays. Structures and linked lists. Static memory, the stack and the heap. Activation records and function calls. Structured programming. Recursion. Object oriented programming. C++ strings, vectors and maps. Creating classes: data members, member functions, constructors and destructors. Encapsulation and information hiding. Derived classes, inheritance and polymorphism. Operator overloading. An overview of Java.
3 credits. Prerequisite: CS102

ECE 164 Data Structures & Algorithms I An introduction to fundamental data structures and algorithms, with an emphasis on practical implementation issues and good programming methodology. Topics include lists, stacks, queues, trees, hash tables and sorting algorithms. Also an introduction to analysis of algorithms with big-O notation. Assignments include programming projects and problem sets.
2 credits. Prerequisite: ECE 161

ECE 165 Data Structures & Algorithms II A continuation of ECE 164, also with an emphasis on practical implementation issues and good programming methodology. Topics include graphs, graph related algorithms and dynamic programming techniques. Also an introduction to some advanced topics such as Turing machines, computability and NP-complete systems. Assignments include programming projects and problem sets.
2 credits. Prerequisite: ECE 164

ECE 193 Electrical & Computer Engineering Projects I (formerly EE 160) An introduction to laboratory techniques for electrical and computer engineering. Electronic test equipment including: DVM, oscilloscope, curve tracer, spectrum analyzer. Circuit analysis and design, discrete and integrated electronic components and circuits. Several projects of limited scope provide an understanding of the fundamental building blocked employed in the more advanced designs in successive projects courses. Students give weekly oral presentations and demonstrate laboratory proficiency through in-class demonstrations and concise, formal technical reports.
1½ credits. Prerequisites: ECE 111, ECE 141 and ECE 150. Non-refundable materials fee: $40

ECE 194 Electrical & Computer Engineering Projects II (formerly EE 161) Principles learned in ECE 193 are applied to the design, construction and characterization of electrical and computer engineering projects of significant complexity. Assignments typically involve both analog and digital design, and students are free to pursue any solution that satisfies the engineering requirements and meets with the instructor's approval. Formal and informal lectures are given on safety, circuit operation and design, and construction techniques; participation in design reviews and technical reports.
4 credits. Prerequisite: ECE 193. Non-refundable materials fee: $40

ECE 195 Electrical & Computer Engineering Projects III (formerly EE 162) ECE 195 and ECE 196 constitute the year-long senior design project. Students work in small groups on projects chosen with the advice and consent of the faculty adviser. Projects may be oriented towards research or product development, and may be in any area of electrical and computer engineering, such as in: computer engineering, signal processing (imaging, sensor arrays, multimedia), telecommunications, computer networks, microwaves, optics, advanced electronics, VLSI chip design, or an interdisciplinary area such as robotics or bioengineering. Students perform all aspects of project management, such as scheduling, budgeting, system design and developing milestones, as well as technical work including hardware and software implementation, testing and performance evaluation. Students also give several spontaneous and rehearsed oral presentations and prepare written reports. Students attend weekly lectures covering: social, economic, legal and ethical issues; safety and laboratory practice; design methodologies; technical writing; preparation of multimedia presentations and tailoring presentations to target audiences.
3 credits. Prerequisite: ECE 194. Non-refundable materials fee: $40

ECE 196 Electrical & Computer Engineering Projects IV (formerly EE 163) This course concludes the senior project begun in ECE 195. Students submit two complete theses, one in short form and the other in long form, and give at least two presentations, one short and one long. The initial goal is to a achieve a functioning system. Afterwards, students undertake the completion of the prototyping cycle, which may involve improving the circuit implementation (such as by employing PCBs populated with surface mount chips), adding a user-friendly interface, obtaining precise performance evaluations, or developing demonstrations and a user's manual. Advanced students are strongly encouraged to complete their project early and commence a master's thesis.
3 credits. Prerequisite: ECE 195. Non-refundable materials fee: $40

ECE 301 Communication Systems Design (formerly EE 301)
Topics in the design of large scale communication systems. Quality of service, system performance calculations, channel capacity and traffic models, scalability. Measurement and simulation techniques. Noise, interference, system noise figure, front-end design, power budgets. Communication electronics. Baseband DSP, IF and RF subsystems. Standards, evolution of technology, product roadmapping. Case studies.
3 credits. Prerequisites: ECE 101 and ECE 135

ECE 302 Probability Models & Stochastic Processes
Topics in probability, random variables and stochastic processes applied to the fields of electrical and computer engineering. Probability, events, random variables, expectation, moments, characteristic functions, conditional probability and expectation. Functions of random variables, random vectors, Gausian random vectors, Poisson points. Bounding and limit theorems. Relations among important distributions and probability models. Stochastic processes: stationarity, ergodicity, Brownian motion, Markov processes. Deterministic systems with stochastic inputs, correlation and power spectral density, ARMA models. Hilbert space and applications: orthogonality principle, discrete Wiener and Kalman filters, linear prediction, lattice filters.
3 credits. Prerequisites: Ma 224 and ECE 101 or ECE 114 or permission of instructor

ECE 305 Computer Security
This course covers attack and defense perspectives of applied information security. Topics will include networked and embedded applications, access controls systems and their failure modes, privilege escalation, case studies and some applied cryptography. Safe practices and OS flaw mitigation will be reinforced through security-sensitive programming projects. Course work will include penetration testing, code auditing and independent programming projects using professional auditing frameworks.
3 credits. Prerequisite: CS 102

ECE 309 Introduction to Cryptography (formerly EE 360)
Selected topics in theoretical and applied cryptography, with an emphasis on "provably secure" systems. One-Time Pads and security in the Shannon sense, cryptographic hash functions, password schemes, basic number theory, hardcore bits, pseudo-random number generators and properties of pseudo-randomness (computational indistinguishability), block and stream ciphers, public key cryptography, message authentication and digital signatures. Real world examples including S/Key, DES, RSA, Diffie-Hellman. Students will have the choice to either program an implementation for a crypto-system or write a research paper.
3 credits. Prerequisites: Ma 111 and Ma 224

ECE 311 System Design for Signal Processing Applications
Design of digital signal processing systems. Implementation of DSP algorithms in programmable and custom VLSI processors. A/D and D/A converters. Real-time systems that handle large amounts of data such as sensor arrays, radar, medical imaging, and multimedia networks.
3 credits. Prerequisites: ECE 114 and ECE 151

ECE 313 Music & Engineering
Spectral representation and analysis of music. Analog and digital music signals, instruments and synthesizers, analog circuits and digital processing. Description of musical quality and perception, introduction to acoustics, stereo and special effects. Computer interfacing with MIDI and laboratory experiments.
3 credits. Prerequisites: ECE111, ECE150

ECE 321 Control Systems Design (formerly EE 372) Control system design using Bode plots, Nichols chart, root locus. Design by pole placement, Ackermann's formula, state-variable feedback. Cascade compensation, minor-loop feedback. Controller and estimator design, regulator systems, systems with a reference input. Introduction to digital control: hybrid analog-digital control systems, sampled-data systems, digital extensions of Bode plots and root locus, Ragazzini's method. Extensive use of MATLAB.
3 credits. Prerequisite: ECE 121

ECE 323 Embedded System Design (formerly EE 381) Hardware and software design for embedded systems. SBC and microcontroller architectures, A/D and D/A conversion, signal conditioning, interfacing and controlling electronic and electro-mechanical systems. Assembly language and high-level language programming, efficient use of computational and physical resources, considerations for speed and robustness, debugging methods, use of simulators and in-circuit emulators. The course is project-based, and students are required to design and construct an embedded system.
3 credits. Prerequisites: ECE 121 and ECE 151

ECE 341 Integrated Circuit Engineering Feedback theory, frequency compensation. Integrated circuit fabrication and technology. Device modeling, thermal effects. VLSI CAD design tools. Circuit layout, extraction and simulation. Design and analysis of multistage MOS operational amplifiers, OTA architectures. Nonlinear circuits, comparators. Analog switches. Digital phase-locked loops. Sample and hold circuits. Data converter architectures. Switched capacitor circuits. Bandgap reference circuits. MOST digital circuit design and layout, hierarchical approaches. Final design project is a mixed analog/digital circuit (e.g., Flash A/D converter, phase-locked loop), which is sent for fabrication.
3 credits. Prerequisites: ECE131, ECE142

ECE 343 Bio-instrumentation and Sensing (formerly EE 391)
The basic human vital signs and some related elementary physiology viewed from an engineering standpoint with special emphasis placed upon current electronic measurement methods. Electrocardiographic and electromyographic signals. Safety problems related to electrical isolation. Guarded, fully isolated, modulated carrier operational amplifiers and microvolt-level amplification. Solid-state "grain of wheat" pressure sensors, microelectrodes, thermal probes, ultrasonic transducers and other biosignal sensors. Course work includes instrumentation and sensing projects.
3 credits. Prerequisites: ECE 114 and ECE 142

ECE 357 Computer Operating Systems Theory and implementation of modern computer operating systems. Message-based and multiprocessor kernels. Networking and interprocess communication. Security, auditing and authentication. Device drivers, interrupt handling, task switching, virtual memory management, scheduling, synchronization and locking. File systems, resource allocation and management. Real-time, fault-tolerant and high security operating systems. User environment and interface issues. Projects in operating system design and programming, case studies.
3 credits. Prerequisites: ECE 150 (Dig. Logic Desc.), ECE 161 (Prog. Lang.)

ECE 361 Software Engineering & Large Systems Design
This course teaches about the development stages of large, robust, expandable software systems developed as part of a team. Topics include project management, capturing requirements, system design, UML, program design, testing, delivery and maintenance. The class will develop a large project as a team using Java throughout the semester. Tools, libraries and techniques necessary for the project will be covered in class, e.g., Eclipse, Javadoc, XML, SOAP, servlets, threads and processes, Swing, JUnit, mySQL, JDBC, etc. The specific resources might change from semester to semester.
3 credits. Prerequisite: ECE165

ECE 391 Research Problem
An elective course open to qualified upper division students. Students may approach an EE faculty member and apply to carry out research on problems of mutual interest in theoretical or applied electrical and computer engineering. Student performs creative work with faculty guidance.
3 credits. Prerequisite: Instructor approval

ECE 392 Research Problem II (continuation of ECE 391)
3 credits. Prerequisite: instructor approval

ECE 399 Selected Topics in Electrical & Computer Engineering (formerly EE 399)
Subjects may include seminars on topics related to advances in technology, current research areas. Also individual research, design and development or study of subjects in electrical and computer engineering.
1-3 credits. Prerequisite: Permission of instructor

Electrical and Computer Engineering (ECE)

Graduate

ECE 401 Selected Topics in Communication Theory (formerly EE 401)
Advanced topics in communications engineering, selected according to student and instructor interest.
3 credits. Prerequisite: ECE101 and permission of instructor

ECE 402 Selected Topics in Probability & Stochastic Processes Advanced topics in applied probability or stochastic processes. Possible areas of study include: Markov processes, queuing theory, information theory, estimation and decision theory and financial engineering. Topics vary year to year.
3 credits. Prerequisite: ECE 302 and permission of instructor

ECE 403 Advanced Communication Networks (formerly EE 407)
A continuation of topics from ECE 103. Technical readings, case studies, and research in network architectures and protocols. Related topics such as distributed computing and ad hoc sensor networks may be covered as well. Topics from probability, stochastic processes and graph theory are presented as needed for the analysis and simulation of communication networks.
3 credits. Prerequisite: ECE 103

ECE 404 Communication Coding (formerly EE 404) Survey of topics from abstract algebra: groups, cosets, polynomials, finite fields. Block codes: cyclic, BCH and RS codes. Convolutional and trellis codes, Viterbi algorithm. Trellis coded modulation. Turbo codes. Performance of error detection and correction schemes in both hard-decision and soft-decision decoding environments. Efficient realizations of encoders and decoders.
3 credits. Prerequisite: ECE 101

ECE 405 Advanced Digital Communications (formerly EE 405)
Advanced digital modulation including formats with memory, continuous-phase and constant-envelope schemes. Performance analysis for AWGN and other channels. Multitone and multicarrier communications. Spread spectrum with applications to multiple access schemes and secure communications. CDMA: PN sequence generation and properties, multi-user detection. Additional topics as time permits.
3 credits. Prerequisites: ECE 101 and ECE 302

ECE 408 Wireless Communications (formerly EE 408) Survey of cellular mobile radio systems and formats, including market trends and technological advances. The emphasis is on CDMA and 3G systems, and emerging schemes such as WiFi networks, although TDMA systems will be discussed as well. Propagation and multipath fading channel models and simulation. Cellular system capacity, traffic models, multiple-access techniques, handoff and power control algorithms. Modulation formats, detection schemes and performance. Mitigating fading: pulse shaping, DFE, MLSE (Viterbi). DSP algorithms for baseband processing.
3 credits. Prerequisite: ECE 101

ECE 409 Advanced Cryptography (formerly EE 460)
Selected topics in theoretical cryptography, with an emphasis on definitions and proofs of security. Security in the Shannon sense, complexity of algorithms and non-deterministic algorithms, one-way functions, trapdoor functions, cryptographic hash functions, number theoretic constructs (such as RSA and Rabin's scheme), hardcore bits and the Goldreich-Levin construction, definition and construction of pseudo-random number generators and pseudo-random function families, computational indistinguishability and the hybrid argument, Feistel Networks and the Luby-Rackoff construction, stream and block ciphers, DES, public-key crypto-systems, semantic security, message authentication codes, digital signature schemes, commitment schemes, and zero knowledge proofs.
3 credits. Prerequisites: ECE 309 and Ma 224; Ma 352 recommended

ECE 410 Radar & Sensor Array Processing Terminology and system overview for modern radar and sensor array systems; antenna parameters; radar signals and waveforms; Doppler processing; detection; synthetic aperture imaging (SAR); beamforming and space-time array processing (STAP); adaptive methods; additional topics may be covered according to student and instructor interest. Computer simulations and readings in the technical literature.
3 credits. Prerequisites: ECE101, ECE114

ECE 411 Selected Topics in Signal Processing Advanced topics in signal processing selected according to student and instructor interest, and instructor approval.
3 credits. Prerequisite: ECE 114 and permission of instructor

ECE 412 MRI Systems
A seminar course covering various topics in magnetic resonance imaging systems and applications. Strategies for design for k-space sampling and pulses. Fast imaging techniques, multi-channel MRI systems. Measurement and analysis of image quality and artifacts. Motion measurement and artifacts. Angiography-imaging blood flow, dynamic imaging of the heart. Various clinical applications. Technical readings and field trips.
3 credits. Prerequisites: Ma 417 and ECE 114, or permission of instructor

ECE 413 Robust Digital Signal Processing (formerly EE 413)
Modern DSP algorithms are presented under the unifying concepts of passivity and structurally lossless realizations. Robust design perform well under non-ideal conditions, such as finite-precision arithmetic and failure of stationarity and other statistical assumptions. The theory of bounded real functions, lossless multiports, realization by extraction and interconnection of elementary lossless building blocks is presented. Applications include mitigating quantization effects in conventional and adaptive filters. Connections are also established with: multirate systems and filter banks; spectral analysis and stochastic realization.
3 credits. Prerequisite: ECE 114

ECE 415 Wavelets & Multiresolution Imaging (formerly EE 415; same as Ma 415)
Wavelet analysis with emphasis on two- and three-dimensional spaces. Time-frequency analysis, multi-resolution analysis (MRA) of signal spaces, Mallat transforms, construction and functional properties of wavelets, connection with multi-rate filter banks. Multidimensional lattices and sampling theory, multidimensional multi-rate systems. PR, QMF and para-unitary filter banks. Techniques for handling boundary effects. Wavelet representation of differential operators with application to image processing. Image and video coding and compression with wavelet transforms. Case studies and technical readings of recent research efforts.
3 credits. Prerequisites: Ma 240 and ECE 111. Taught jointly by electrical engineering and mathematics faculty

ECE 416 Adaptive Filters (formerly EE 416) Statistical signal processing theory: discrete-time Wiener and Kalman filters, linear prediction, steepest descent and stochastic gradient. LMS, normalized LMS, LS, RLS, QR-RLS, order-recursive algorithms. Applications include equalization, noise cancellation, system identification, sensor array processing. Numerical linear algebra: eigenanalysis, SVD, matrix factorizations. Transversal filters, lattice filters, systolic arrays. Performance: convergence, learning curves, misadjustment, tracking in nonstationary environments. Additional topics such as adaptive IIR filters, neural networks and quantization effects may be covered as time allows. Extensive use of MATLAB.
3 credits. Prerequisite: ECE 302 or permission of instructor

ECE 417 DSP System Design (formerly EE 417) Design of programmable and custom digital signal processors, and realization of DSP algorithms in specialized architectures. Features of programmable DSPs such as data-stationary and time-stationary coding, MAC and ACS ALUs, circular buffers. Very Long Instruction Word (VLIW) processors. Applications of graph theory and passivity theory to map DSP algorithms to custom structures: SFGs, DFGs, retiming, folding and unfolding, lattice and orthogonal filters, scheduling and allocation, systolic architectures. Optimization with respect to number of hardware units, speed (sample period and latency), VLSI area, power consumption and performance (quantization effects). Special CAD tools and languages for rapid prototyping. Case studies and programming exercises.
3 credits. Prerequisites: ECE 114 and ECE 151

ECE 418 Digital Video (formerly EE 418) Digital video coding, compression, processing and communications. Target applications from low bit-rate, low quality to high bit-rate, high quality. Two- and three-dimensional sampling, color spaces, motion representation. Motion estimation: optical flow, block-matching; constrained optimization: Bayesian methods, simulated annealing, Gibbs random fields. Mathematical basis for compression standards such as JPEG and MPEG, and digital television including HDTV. Rate-distortion based compression for optimal bit allocation via dynamic programming (Viterbi algorithm). Scalability in multimedia systems.
3 credits. Prerequisite: ECE 114

ECE 421 Advanced Control System Design (formerly EE 471)
Design of control systems using two-degrees of freedom and PID compensators. Ackermann's formula, H-infinity control theory and applications. Analysis and design for nonlinear systems using describing function, state-variables, Lyapunov's stability criterion and Popov's method. Introduction to optimal control theory (dynamic programming). Design problems and extensive use of MATLAB.
3 credits. Prerequisites: ECE 114 and ECE 121

ECE 422 Selected Topics in Embedded Systems (formerly EE 482) A project oriented interdisciplinary course, where students design and construct embedded systems for particular applications. Aspects of mechanics, robotics, process control, bioengineering, communications, electronics, motors and motor drivers, sensors, actuators, signal conditioners, interfaces, computer hardware and computer programming. Problems encountered in real systems including: interrupts, timing, grounding, thermal and noise effects, documentation, reliability.
3 credits. Prerequisite: ECE 323

ECE 423 Digital & Microprocessor Control (formerly EE 464)
A project oriented interdisciplinary course on microprocessor based control systems. Process control, PID algorithm, numerical machine tool control, robotics, measuring and controlling thermal, electrical, mechanical, biomedical and chemical systems. Considerations of overall system stability, logic design, response time and the design of algorithms. Student projects.
3 credits. Prerequisites: ECE 151 and ECE 121

ECE 425 Digital Control Systems
Basic components of digitally controlled dynamic systems. Sampling and reconstruction: the ideal sampler, zero and higher order hold elements. The pulse transfer function and the z-transfer function description of dynamic systems. Stability criterion and analysis by the Nyquist, root locus and Bode methods. The modified Routh-Hurwitz and Jury stability criteria. The state-variable approach: state equations of dynamic systems with sample and hold devices, state equations of systems with all digital elements. Digital simulation and approximation. Controllability, observability and stability. State and output feedback, state observers and the separation principle. Digital control system design by state feedback.
3 credits. Prerequisites: ECE 121 (Control Systems)

ECE 431 Microwave Engineering (formerly EE 421)
Passive circuits, open-boundary waveguides, perturbation theory, coupled modes, waveguide junctions, microstrip. Two- and three-terminal devices; varactor diodes, Gunn diodes; IMPATT and MESFET technology. Design of RF amplifiers and phase-shifters. Computer aided simulation and design.
3 credits. Prerequisite: ECE 135

ECE 433 Optical Communications Devices & Systems (formerly EE 406) PIN, avalanche and Schottky photodiodes; risetime, noise, amplifier requirements. Semiconductor optical devices: radiative and non-radiative recombination, quaternary semiconductors, heterojunctions, quantum wells, bandwidth minimization, lasers, distributed feedback, vertical cavity structures. Internal and external modulation, electro-optic modulators, Stark effect. Optical fibers: mode structure, attenuation, dispersion, PM fibers, WDM. System architecture, analog/digital communications, terabit data links. Solitons.
3 credits. Prerequisite: ECE 131 and ECE 135

ECE 441 Digital Integrated Circuit Engineering Design of static and dynamic CMOS combinational logic gates, layout and simulation. Standard cell construction. Sequential logic systems—registers, latches, clocks. Design of arithmetic building blocks, ALU, multipliers. Memory circuits and organization. FPGAs. System design—hardware description languages, floorplanning, system architecture. A major component of the course is the design and fabrication of an ASIC using a variety of VLSI CAD tools.
3 credits. Prerequisite: ECE341

ECE 442 Communication Electronics
Circuit design for advanced communications applications. Design of high-frequency amplifiers, oscillators and mixers using large signal analysis. Effects of noise and non-linearities are examined from the diode and transistor level to board level. Communication subsystems of interest include phase locked loops, modulators and demodulators (AM, PM FM), and signal processors for multiple access systems (TDMA, FDMA, CDMA). Course work includes computer-aided simulation and design projects.
3 credits. Prerequisites: ECE 101, ECE 135 and ECE 142

ECE 443 Thin-Film Electronics (formerly EE 440) Properties of polycrystalline, amorphous, liquid and organic semiconductors. Methods of deposition: vacuum and nonvacuum techniques, epitaxial and nonepitaxial growth. Assessment of thin film semiconductors: structural, optical, electrical. Thin film semiconductor devices: transistors, displays, photovoltaics, flexible conductors. Optical coatings and architectural applications. Thin film superconductors: metallic, allow and high Tc, fabrication and assessment. Superconducting devices: Cooper pairs, Josephson junctions, SQUIDS, Josephson computers.
3 credits. Prerequisites: ECE 131 and ECE 142

ECE 445 Design with Operational Amplifiers Analysis and design of operational amplifier circuits with various applications, including amplifiers, filters, comparators, signal generators, D/A and A/D converters and phase-locked loops. Introduction to issues such as static and dynamic limitations, noise and stability. Use of industry standard CAD software.
3 credits. Prerequisite: ECE142

ECE 453 Advanced Computer Architecture This course studies modern, advanced techniques used to design and produce current, state-of-the-art computer architectures. Technology, performance and price. The quantitative principle and Amdahl's law. Instruction sets; addressing modes, operands and opcodes; encoding instruction sets. RISC versus CISC architectures; MIPS. Pipelining; the classic five-stage pipeline, hazards, exceptions, floating point operations. Advanced pipelining techniques: dynamic scheduling, branch prediction. Multiple issue, speculation. Limits of parallelism. Compiler support for parallelism, VLIW. Caches. Examination of modern processors.
3 credits. Prerequisites: ECE151

ECE 457 Selected Topics in Operating Systems
Advanced topics in operating systems, selected according to student and instructor interest.
3 credits. Prerequisites: ECE 151 and ECE 161

ECE 461 Advanced Programming Methods This course addresses the need for engineers to craft algorithmic solutions to problems of ever-increasing complexity. The curriculum includes consideration of the man-machine interface, real-time control, remote sensing and computing in a distributed environment. Software fault tolerance and reliability and unbreakable database transactions. Computer network security and network reliability, safety of data through authentication and encryption. Engineering trade-offs between efficiency and portability and design for maintenance.
3 credits. Prerequisitse: ECE151, ECE165

ECE 462 Interactive Engineering Graphics (formerly EE 452)
Graphical primitives, windows, clipping and viewports. Two- and three-dimensional geometric transformations and translations; rotation, pan and zoom. Hidden line and surface removal. Region filling and shading. The architecture of high performance graphical engines. Representing lighting, shading and textures. Rendering. Rotation. GUIs. Animation. Course work includes design projects.
3 credits. Prerequisites: ECE 151 and ECE 165

ECE 463 Web 2.0 Architecture & Development
Software engineering and networking issues related to the development of Web 2.0 solutions, focusing on mobile, web and voice applications. Coursework includes software projects and case studies.
3 credits. Prerequisites: ECE103, ECE165 or permission of instructor

ECE 464 Databases (formerly EE 454) Database architecture. Relational, hierarchical and network data models. Data sublanguages, relational algebra and relational calculus. Data independence and integrity. The database management system. Security and privacy, logs. Low-level file structures, organization and indexing. Data compression, protection and encryption. Distributed databases. Course work involves the design of relational systems using commercial packages, followed by the design and implementation of a small general database built around relational algebra.
3 credits. Prerequisite: ECE 165

ECE 466 Compiler Theory (formerly EE 456) Regular expressions, production systems, grammars and language theory. Phases of compilation: lexical analysis, parsing and code generation. Standard compiler design tools such as Lex and YACC. Syntax directed translation, symbol tables and space reservation. Error detection at compile-time and run-time. Code generation and the run-time environment. Elements of code optimization. Course work involves the implementation of a compiler for a restricted language using standard tools and custom code.
3 credits. Prerequisites: ECE 151 and ECE 165

ECE 468 Computer Vision (formerly EE 458) Visual perception and imaging geometry. Pixels, pixel neighborhoods and pixel connectivity. Image transforms: Fourier, Hadamard, Walsh, Discrete Cosine, Haar, Slant and others. Techniques for image manipulation and enhancement in both the frequency and spatial domains. Histogram equalization, image subtraction and local averaging. Filtering, homomorphic methods. Color models and use of monochrome techniques on RGB channels. Image restoration: camera movement cancellation, scratch removal. Image compression techniques, lossy and lossless. Image segmentation, edge detection, edge linking, boundary detection; region growing, splitting and merging. Image representation as a hierarchical collection of objects, chain codes, Fourier descriptors. Object recognition, signatures.
3 credits. Prerequisites: ECE 111, ECE 151 and ECE 161

ECE469 Artificial Intelligence
This course covers many subtopics of AI, focusing on a few important subtopics in detail. The "intelligent agent" approach is explained and forms a foundation for the rest of the course. Intelligent search: uninformed search, depth-first search, breadth-first search, iterative deepening; informed search, best-first search, A*, heuristics, hill climbing; constraint satisfaction problems; intelligent game playing, minimax search, alpha-beta pruning. Machine learning: probability, Bayesian learning; decision trees; statistical machine learning, neural networks, Naive Bayes, k-nearest neighbors, support vector machines. Natural language processing: syntax, semantics and pragmatics; real-world knowledge; parsing; statistical NLP. Philosophy of AI: AI and consciousness, the Turing test, the Chinese room experiment. Coursework includes two large individual programming projects.
3 credits. Prerequisite: ECE165

ECE 491 Selected Topics in Electrical & Computer Engineering (formerly EE 491)
Subjects may include study in electrical and computer engineering, or seminars on topics related to advances in technology, This course may not be used to expand the number of credits of thesis, or cover material related to the thesis.
1-3 credits. Prerequisite: Permission of instructor

ECE 499 Thesis/Project (formerly EE 499) Master's candidates are required to conduct, under the guidance of a faculty adviser, an original individual investigation of a problem in electrical and computer engineering and to submit a written thesis describing the results of the work.
6 credits over 1 year

Electrical Engineering (EE-coded)

Undergraduate

EE 121 Circuits, Signals & Systems I Circuit elements and waveforms, network equations, loop and nodal analysis, matrix representations, systematic and "shortcut" methods. Transient analysis of first, second and higher order circuits, initial conditions, visualization in the complex plane. Sinusoidal steady-state, phasors, complex power. Laplace transforms with applications to circuit analysis. Introduction to systems analysis. Several assignments involve computer analysis of circuits, signals and systems.
3 credits. Prerequisite: Ma 113

EE 122 Circuits, Signals & Systems II Network theorems, network functions, two-port and multi-port parameters. Frequency response plots, resonance, stability. State-space equations, time-domain and Laplace domain solution of state-space equations. Fourier series and Fourier transforms. Analog filter design, passive and active filter realizations. Analysis and design using MATLAB.
3 credits. Prerequisite: EE 121

EE 125 Engineering Electromagnetics I
Electrostatics, magnetostatics, dielectrics, boundary value problems. Maxwell's equations. Potential, power, polarization, boundary conditions, lossy and lossless media. Plane waves, transmission lines, Smith chart, impedance matching, reflection and refraction.
3 credits. Prerequisites: Ma 223 and Ph 213

EE 126 Engineering Electromagnetics II
Guided waves, TE and TM modes, cylindrical waveguides with rectangular and circular cross-section, cavity resonators. Linear networks and scattering parameters. Antenna dipoles, apertures, antenna arrays, radiation patterns. Introduction to optical and microwave systems and devices, with applications to communications and signal processing. Every student uses a vector network analyzer.
3 credits. Prerequisites: EE 125

EE 141 Electronic Devices & Circuits I Semiconductor principles. PN junction theory, diodes, diode models and circuit applications. Bipolar and field effect transistors: devices, models and the four basic circuit configurations. Linear BJT and FET amplifiers, discrete and integrated models, biasing, single stage, cascaded stages. Survey of integrated circuit fabrication techniques. Theoretical principles are supplemented with design problems.
3 credits. Prerequisite: EE 121

EE 142 Electronic Devices & Circuits II MOS circuits: DC operation and analysis. Single stage MOS amplifiers, circuit design, DC and small signal analysis. Cascode amplifier. Current mirrors, active loads, BJT and MOS differential amplifiers. Monolithic operational amplifiers. Output stages. Frequency response. Introduction to feedback theory, amplifier topologies. Circuit design and analysis are supplemented with industry standard CAD.
3 credits. Prerequisites: EE 122 and EE 141

Mechanical Engineering Courses

Undergraduate

ME 100 Stress and Applied Elasticity Three-dimensional theory of elasticity; state of stress, state of strain, elastic stress-strain relations. Applications include elementary three-dimensional problems, plane stress and plane strain, Saint Venant's long cylinder, beams and plates. Computer-aided design projects.
3 credits. Prerequisite: ESC 101

ME 101 Mechanical Vibrations
Mechanical systems with single and multiple degrees of freedom; longitudinal, torsional and lateral vibrations; free and forced oscillations; vibration testing, dynamic stability, vibration isolation, design criteria. Computer-aided design assignments.
3 credits. Prerequisite: ESC 101

ME 105 Drawing and Sketching for Engineers (same as EID 105)

ME 107 Computer-Aided Analysis and Design Techniques
Skill in use of computer-aided analysis and 3D-design software in solving engineering problems and in creating and visualizing engineering designs is among the most basic of an engineer's toolbox. This course takes students through a hands-on learning experience in the practice of a contemporary analysis tool, such as MATLAB, and a contemporary 3D-design tool, such as SolidWorks. Topics include data structuring and programming; numerical modeling and analysis; technical drawing and engineering graphics; conception and a visualization of 3D engineering models, parts and assemblies; and detailed generative 2D drawings.
1.5 credits

ME 116 (same as EID 116) Musical Instrument Design
Theory and use of musical scales, including just intonation and equal temperament systems. Musical harmony and basic ear training. Human hearing and the subjective measures of sound: pitch, loudness and timbre. Acoustic analysis of design and operating principles of traditional instruments, including members of the percussion, string and wind families. Prototyping and testing of original musical instrument concepts.
3 credits. Prerequisite: permission of instructor

ME 120 Design Elements
Application of the principles of mechanics to the design of basic machine elements; study of components subjected to static, impact and fatigue loading; influence of stress concentration; deflection of statically determinate and indeterminate structures by the energy method. Design projects apply basic criteria to the design of shafts, springs, screws and various frictional elements; design projects make use of computer, experimental and modeling techniques.
3 credits. Prerequisite: ME 100

ME 130 Advanced Thermodynamics Equations of state; properties of pure substances; ideal and real gas and gas-vapor mixture properties, fundamental process and cycle analysis of ideal and real systems; modern gas and vapor power cycles and refrigeration cycles. Computer applications to problem solving.
3 credits. Prerequisite: ESC 130

ME 131 Energetics (same as EID 131) Current and near-term energy sources, including coal, oil, natural gas, nuclear fission, hydroelectric, oil shale and refuse. Description of contemporary methods of energy conversion including conventional utility power plants and nuclear power plants. Introduction to direct energy conversion; magneto-hydrodynamics, fuel cells, thermionic and thermoelectric. Design of the thermodynamic operation of a steam power plant.
3 credits. Prerequisite: ESC 130

ME 133 Air-Conditioning, Heating and Refrigeration (same as EID 133) Introduction to air-conditioning, heating and refrigeration, with emphasis on application of thermodynamics, fluid dynamics, mass transfer and heat transfer; psychometrics, cycles, load calculation, component and system performance; absorption, refrigeration, heat pumps, solar heating and cooling.
3 credits. Prerequisite: ESC 130, ESC 140

ME 140 Gas Dynamics
Integral form of the conservation equations; one-dimensional compressible flows, including isentropic flow, isothermal flow, flow with friction, flow with heat transfer and normal and oblique shock waves; generalized one-dimensional flow. Computer applications and a semester-long design project.
3 credits. Prerequisites: ME 130, ESC 140

ME 141 Fundamentals of Aerodynamics Study of incompressible potential flow around bodies of aerodynamic interest, by the use of equations of motion, method of singularities and conformal transformation. Investigation of experimental results and techniques. Consideration of the effects of viscosity and transition from laminar to turbulent flow. A design-oriented project, usually involving application of computer methods, will be required.
3 credits. Prerequisite: ESC 140

ME 142 Heat Transfer: Fundamentals and Design Applications One-dimensional steady-state conduction. Two-dimensional steady-state conduction and transient conduction: finite-difference equations and computational solution methods. Convection; introduction to laminar and turbulent viscous flows; external and internal forced convection problems, including exact and numerical solution techniques; free convection. Introduction to radiation heat transfer and multimode problems. Open-ended design projects will include application to fins, heat exchangers, tube banks and radiation enclosures and will make use of computer-aided design techniques.
3 credits. Prerequisite: ESC 140

ME 151 Feedback Control Systems
Modeling and representation of dynamic physical systems: transfer functions, block diagrams, state equations, and transient response. Principles of feedback control and linear analysis including root locus and frequency response methods. Practical applications and computer simulations using MATLAB. Discussions of ethics will be integrated into the curriculum.
3 credits. Prerequisite: Ma 240, ESC 161

ME 153 Mechatronics (same as EID 153) Topics include computer architecture, PIC processor overview, dynamic modeling, sensors, data acquisition, digital PID control theory, and utilization of assembly language to code the controller. Students will design, build and test a controller board and present a final prototype of a control system. Engineering economics will be introduces and integrated into the final project.
Prerequisite: ME 151 or ECE 121 or ChE 152

ME 155 Design and Prototyping
A mechanical engineering hands-on workshop geared towards the understanding and practice of basic engineering design and fabrication tools. Topics include hand tools, simple machining, mold making, casting, materials, fasteners, adhesives, and finishes. 3-D digitizing, solid modeling, rapid prototyping and computer interfacing will also be presented. Team projects will familiarize the students with typical tools and processes employed in realizing a design concept, from sketch to functional prototype. Each student will participate in and contribute to the team-learning and creation process.
2 credits. Prerequisite: EID 101

ME 160 Engineering Experimentation Selection, calibration and use of subsystems for the measurement of mechanical, thermal/fluid and electrical phenomena. Laboratory work includes investigations of heat exchangers, fluid systems and internal combustion engines. Emphasis is placed on data collection and statistical reduction, computational methods and written and oral presentation skills.
3 credits

ME 163 Mechanical Engineering Projects Original investigations, involving design and experimental work which allow the application of engineering sciences to the analysis and synthesis of devices or systems and permit the deepening of experience in engineering decision making. Projects are carried out in small groups and are supervised by the instructor in accordance with professional practice.
3 credits. Prerequisite: permission of instructor

ME 164 Capstone Senior ME Design The application of open-ended design work to the synthesis of engineering devices and systems for the satisfaction of a specified need. Consideration of market requirements, production costs, safety and esthetics. Projects are carried out in small groups and are supervised by the instructor in accordance with professional practice. The goal of the course is to create a working design, clearly defined in drawings and specifications.
3 credits. Prerequisite or co-requisite: ME 163

ME 165 (same as EID 165) Sound and Space Basics of acoustics, including sound waves, room and hall acoustics and metrics of sound. Audio engineering, including microphones, signal processors, amplifiers and loudspeakers. Skills and techniques using Pro Tools brand audio editor system to create original sonic and musical compositions. Public exhibition of an electronic music program.
3 credits. Prerequisite: permission of instructor

ME 300 Space Dynamics
Fundamental principles of advanced dynamics; kinematics, transformation or coordinates; particle and rigid body dynamics. Application to space problems; satellite orbits; gyro-dynamics, space vehicle motion; performance and optimization. Generalized theories of mechanics; virtual work, D'Alembert's principle; Lagrange's equation; Hamilton's principle.
3 credits. Prerequisite: ESC 100

ME 312 Manufacture Engineering (same as EID 312) Study of metal processing theory and application with emphasis on casting, machining, and metal deformation processes; plastic forming; special processing techniques; work-holder design principles. Specific areas studied include stages of processing, mathematical modeling of processes, equipment determination, relationship of plant layout, tooling, metrology, and product design to product cost.
3 credits. Prerequisite: EID 101

ME 313 Science of Materials for Engineering Design (same as EID 313) This course is intended to give the student the tools with which to design with materials: to choose an existing material for a new application or design the ideal material to replace one in use. The materials studied cover the full range: metals, ceramics, glasses, polymers, composite materials and wood. Topics include phase diagrams and phase transformations, structure and strength, normal use and failure, all with an eye on design.
3 credits. Prerequisite: ESC 110 or ESC 110.1

ME 314 (same as EID 314)
3 credits. Prerequisites: ESC 101, ESC 110 or ESC 110.1

ME 320 Mechanical Design
Mechanical design of basic transmission elements; design optimization by blending fundamental principles and engineering judgment; design criteria for the various frictional machine elements. Design projects provide authentic involvement in problems from industry; design projects make use of computer, experimental and modeling techniques.
3 credits. Prerequisite: ME 120

ME 321 Engineering Kinematics
Study of motion conversion through various types of mechanical components, using analytical and graphical techniques. Velocity and acceleration analysis; special kinematic devices, synthesis of mechanisms; linkage design. Theory applied to creative project assignments.
3 credits. Prerequisite: ESC 100

ME 322 Dynamics of Machines
Application of mechanics to rigid bodies as found in machines and machine elements. Dynamics of machines as influenced by the kinematics of the motion, externally applied forces and self-generating inertia forces.
3 credits. Prerequisite: ME 101

ME 330 Advanced Engine Concepts
Development of energy efficient, high-output, cleaner engine systems. Broad analytical and experimental review of the governing parameters involved in engine design and optimization. Topics include thermodynamics, fluid mechanics, heat transfer, combustion, emissions, thermochemistry, dynamic and static loading, and fuel efficiency, as they apply to different engine cycles and types. Research examples from industry, government, and academia are reviewed. Stationary and mobile applications, with particular emphasis on automotive engine design are analyzed. Hands-on learning skills are developed through computational and experimental assignments.
3 credits. Prerequisite: ME 142

ME 332 Internal Combustion Engine Design Increasingly stringent environmental and economic climates have prompted the development of energy-efficient, high-output, cleaner engine systems. This course is a broad analytical and experimental review of the governing parameters involved in engine design and optimization. Topics involve thermodynamics, fluid mechanics, heat transfer, combustion, emissions, thermochemistry, dynamic and static loading and fuel efficiency, as they apply to different engine cycles and types. Research examples from industry, government and academic are reviewed. Stationary and mobile applications, with particular emphasis on automotive engine design, are analyzed from first principles. Students develop hands-on learning skills through computational and experimental assignments.
3 credits. Prerequisite: ME 142 or permission of instructor

ME 334 Combustion (same as EID 334) Thermodynamics and kinetics of reacting systems. Conservation laws for reacting gas mixtures. Gas phase and heterogeneous phase diffusion flames, including supersonic diffusion flames and fuel droplet combustion in liquid propellant rocket engines and in residential oil burners. Premixed flames in gases. Detonation waves in gases. Examples of current research in aerospace and environmental aspects of combustion processes.
3 credits. Prerequisite: ESC 141 or ME 142

ME 340 Advanced Aerodynamics
Study of ideal compressible flow around aerodynamic bodies by the use of linearized subsonic and supersonic theory. Investigation of computational techniques and experimental methods and results. Consideration of real gas and viscous effects and hypersonic flow.
3 credits. Prerequisites: ESC 130 and ME 141

ME 343 Fluid Machinery
The application of fluid mechanics and thermodynamics to the analysis and design of turbomachines. Topics to be studied include theory and three-dimensional flows. Both axial and radial flow fans, blowers, compressors, pumps and turbines will be considered as well as special topics in turbo-machinery. A design project, usually involving application of computer methods, will be required.
3 credits. Prerequisites: ESC 130, ESC 140

ME 352 Advanced Control Theory (same as EID 352)
Tools and methods of control system design and compensation; simulation, specifications, frequency domain techniques, state variable feedback, sensitivity analysis. Specific topics covered are controllability, observability, Lyapunov stability, pole placement technique, full order observers, reduced order observers and output feedback. Emphasis will be placed on modern control theory. Group design project to build working prototype. Both engineering economics and ethics will be addressed when presenting the final working prototype.
3 credits. Prerequisite: ME 151 or ECE 121 or ChE 152

ME 353 Transducers, Sensors and Computer Interfacing (same as EID 353) Transducers and sensors are widely used in engineering and scientific research and as an integral part of products and automated systems. Students will be introduced to numerous available techniques for sensing displacement, force, pressure, acceleration, temperature, radiation and other physical parameters; digital computation and digital transducers; computer interfacing such as analog signal conversion, signal processing, interface components, communication; software systems such as programming real-time systems and real-time operating systems. The instructor will present case histories of several industrial instrumentation and sensing systems. Projects provide authentic involvement in problems from industry that require computer interfacing and experimental techniques.
3 credits. Prerequisite: permission of instructor

ME 356 Digital Control and Non-linear Control (same as EID 356)
Introduction to digital control systems, z-transformations, discrete equivalents to continuous transfer functions, design of digital controllers, non-linear control theory. Laboratory experiments will be performed which will include control of the speed of a motor through computer programming.
3 credits. Prerequisite: ME 151

ME 363-364 Selected Topics in Mechanical Engineering
This course will deal with current technological developments in various fields of mechanical engineering. Projects and design will be emphasized.
3 credits each. Prerequisite: ME faculty permission

ME 365 Mechanical Engineering Research Problem
An elective course available to qualified students. Students may elect to consult with an ME faculty member and apply to carry out independent research on problems of mutual interest in theoretical or applied mechanical engineering.
3 credits. Prerequisite: ME faculty permission and senior standing. May be repeated

Graduate

ME 401 Advanced Mechanical Vibrations Combined analytical and experimental approach to mechanical vibration issues; characterization of the dynamic behavior of a structure in terms of its modal parameters; digital data acquisition and signal processing; experimental modal analysis procedures and excitation techniques; extraction of modal parameters from measured frequency response functions. Students will acquire hands-on experience with impact hammer and shaker data acquisition and analysis.
3 credits. Prerequisite: ME 101

ME 402 Advanced Stress Analysis
Elements of stress and deformation analysis. Numerical and analytical techniques include finite difference, relaxation, finite element, complex variables and energy and variational methods. Applications include torsion, two-dimensional problems, bending of bars, elastic stability, wave propagation, thin plates and shells and curved beams and plates.
3 credits. Prerequisite: ME 100

ME 403 Advanced Engineering Dynamics Elements of classical dynamics: kinematics, kinetics, work and energy, impulse and momentum, vibration. Motion of a system of particles and rigid bodies. Lagrangian dynamics.
3 credits. Prerequisite: ME 101

ME 405 Automotive Engineering Fundamentals An introductory course in modern automotive design, covering aspects of prime movers, aerodynamics, brakes, tires, steering, transmission, suspension and handling, chassis and advanced hybrid powertrain concepts. Simulations and physical prototyping give students a hands-on approach to the design, optimization, fabrication and testing of various vehicle subsystems in a team-based learning environment.
3 credits. Prerequisite: ME 130 or permission of instructor

ME 407 Introduction to Computational Fluid Dynamics
The need for and applications of computational fluid dynamics (CFD). Introduction to CFD analysis and commercially available codes. Governing equations and numerical solution methodologies for basic fluid flow systems. Geometric modeling and grid generation. Examination of various physical models. Use of a commercial CFD code.
3 credits. Prerequisite: ESC 140

ME 410 Materials and Manufacturing Process (same as EID 410) In manufacturing operations, materials are subjected to large forces for producing useful shapes. This course attempts to establish an understanding of the behavior of materials in response to such forces. Topics covered will include elastic behavior, plasticity, strengthening mechanisms, basic manufacturing processes and testing. Vital aspects of the continuum behavioral response of materials to manufacturing processes will be covered emphasizing the mechanical and metallurgical factors that control the processes.
3 credits

ME 412 Autonomous Mobile Robots
This course introduces basic concepts, technologies, and limitations of autonomous mobile robots. Topics include digital and analog I/O, tactile sensing, IR sensing and range finding, light sensing, sonar, magnetic field sensing, encoders, DC motor actuators, servo motor actuators, high-level microprocessor control, low-level microprocessor control, power management, and prototyping. Students will form teams to design and build autonomous mobile robots configured to compete with each other in a singles-match game, or to perform a team-oriented task.
3 credits. Prerequisite: ME 153 or ECE 151

ME 413 Microelectromechanical Systems (MEMS) Advances in the design, fabrication, analysis and control of mircoelectromechanical systems (MEMS) have positioned MEMS at the forefront of high-value, cutting-edge technologies. The scope of this course covers both the fundamental and advanced aspects of MEMS. Topics include introduction to MEMS, materials and fabrication processes, sensors and actuators, microfluidics, scaling principles, device concepts and system design. MEMS processing simulation and modeling, testing and packaging of MEMS will also be presented. Furthermore, exposure to basic MEMS processing and cleanroom protocol will be included.
3 credits. Prerequisite: ESC 110 or ESC 110.1

ME 415 Introduction to Nanotechnology Understanding and control of matter at dimensions in the range from one to 100 nanometers for novel applications are the main objectives of nanotechnology. The scope of this course encompasses nanoscale science and engineering. Typical topics will include the unique properties of some nanometer scale materials, processiong and fabrication technologies for nanomaterials, imaging, measuring, modeling and manipulating matter at this length scale. In addition, laboratory demonstrations on nanomaterials processing, nanoarchitecturing and self-assembling of nanostructures will be included.
3 credits. Prerequisite: ESC 110 or ESC110.1

ME 417 Mechanobiology
Mechanical factors play important roles in development, maintenance of healthy tissue, the initiation of disease and the development of repair strategies. This course will introduce students to the principles and disease, and the development of repair strategies, as well as to the principles and concepts of mechanobiology through the investigation of recent work in the field. Specific topics will include mechanical regulation of cell behavior, applications to tissue engineering, mechanotransduction and experimental techniques.
3 credits. Prerequisities: ESC 101 and Bio 101, or permission of instructor

ME 420 Axiomatic Design (same as EID 420).
3 credits. Prerequisite: permission of instructor

ME 421 Rehabilitation Engineering (same as EID 421)
3 credits. Prerequisite: permission of instructor

ME 423 Measurement of Human Performance (same as EID 423)
3 credits. Prerequisite: permission of instructor

ME 425 Product Design I (same as EID 425)
3 credits

ME 426 Product Design II Continuation of ME/EID 425
3 credits. Prerequisite: ME/EID 425

ME 430 Thermodynamics of Special Systems (same as EID 430 and ChE 430)
3 credits. Prerequisite: ME 130

ME 431 Heat Convection
Conservation equations; forced convection in laminar and turbulent flows; natural convection; combined natural and forced convection; heat transfer at high velocities, special heat transfer problems.
3 credits. Prerequisite: ESC 141

ME 432 Heat Conduction and Radiation Theory of heat conduction in isotropic and anisotropic solids; analytical, graphical and numerical solutions to steady- and non-steady-state heat conduction equations. Thermal radiation in absorbing and non-absorbing media. Application to selected problems involving combined energy transport mechanisms and to heat transfer problems of current interest.
3 credits. Prerequisite: ESC 141

ME 434 Special Topics In Combustion (same as ChE 434)
Analysis of diffusion and premixed flame processes, including droplet and particle flames, combustion in sprays, chemical reactions in boundary layers, combustion instability in liquid and solid rocket engines and gas burner flames. Consideration of ignition and quenching processes and flammability limits.
3 credits. Prerequisite: ME 334

ME 440 Advanced Fluid Mechanics (same as EID 440 and ChE 440)
3 credits. Prerequisites: ESC 140 and permission of instructor

ME 451 Introduction to Applied Optimal Control Theory and Design
An introduction to the concepts and techniques utilized in the analysis and design of optimal (deterministic) control systems. Topics include a review of state-space control systems concepts; reduced order observers and state-feedback controllers; basic theory of linear quadratic optimal control; standard regulator problem; optimal tracking systems; introduction to the calculus of variations and functional optimization; utilization of computer-aided optimal control systems design software such as MATLAB. Techniques developed will be applied, in the form of student design projects, to a variety of challenging control systems design problems.
3 credits. Prerequisite: ME 151 or ECE 121 or ChE 152

ME 453 Computer-Aided Design/ Computer-Aided Manufacturing (CAD/CAM) (same as EID 453)
Computer design aids, languages, databases, and data structures; geometric modeling; rapid prototyping; design verification, simulation, and testing; investigation of commercial CAD/CAM packages. Student projects include geometric modeling with commercial CAD/CAM packages, team-based product design, and programming of basic CAD applications. Students are grouped into design teams and are expected to work

on a term project starting with specifications, carrying out the full work and documentation of actual design processes.
3 credits. Prerequisite: ECE 161

ME 455 Optimal Estimation Methods (same as EID 455)
Introduction to linear and nonlinear estimation methods with emphasis on both theory and implementation. Batch and sequential strategies, real-time and post-experiment estimation are covered. Includes both parameter estimation and state estimation. Topics covered are a review of probability and optimization, parameter estimation (linear and nonlinear least squares), minimal variance and maximum likelihood estimation, system identification and estimation, Kalman filtering, smoothing, covariance propagation for continuous and discrete systems as well as linear and nonlinear, real-time and post-processing and minimum model error estimation. Students will work on realistic problems such as global positioning using geosynchronous satellites. MATLAB software used extensively.
3 credits. Prerequisite: ME 151 or ECE 121 or ChE 152

ME 457 Optimization Techniques for Design (same as EID 457)
Optimization techniques with applications in various aspects of engineering design. Concepts of design variables, constraints, objective functions, penalty functions, Lagrange multipliers. Techniques for solving constrained and unconstrained optimization problems: classical approaches, steepest descent, conjugate directions, conjugate gradient, controlled random searches, etc. Discussion of generalized reduced gradient, sequential linear programming, and recursive quadratic programming strategies. Special topics will be discussed such as optimum sensitivity analysis, multilevel optimization, and integer programming. Computer implementation of optimization schemes. Applications and examples in the design of engineering components and systems. A design project will be assigned that will require the use of several optimization schemes.
3 credits. Prerequisite: Ma 223

ME 458 Industrial Robots (same as EID 458) Basic concepts, techniques, and limitations of modern industrial robots; industrial automation; robot programming languages; definition and description of a robot work space; application of transform and operator matrices in industrial robotics. Student projects include computer programming of forward and inverse kinematics, and application programming with an industrial robot.
3 credits. Prerequisite: ECE 151

ME 464 Computer-Integrated Manufacturing (same as EID 464)
Fundamentals of computer-aided design, analysis, and manufacturing; geometric modeling, IGES, PDES, and STEP; rapid prototyping; mechanism simulation and finite element analysis; CNC part programming and machining; group technology and process planning. Student projects emphasize concurrent engineering and teamwork.
3 credits. Prerequisite: ME 312

ME 470 Microelectromechanical systems (MEMS) This course covers the fundamental and advanced aspects of MEMS. Topics include introduction to MEMS, materials and fabrication processes, sensors and actuators, microfluidics, scaling principles, device concepts and system design. MEMS processing simulation and modeling, testing and packaging of MEMS will also be presented. Exposure to basic MEMS processing and clean-room protocol will be included.
3 credits. Prerequisite: ESC 110

ME 493-494 Selected Advanced Topics in Mechanical Engineering
These courses will deal with current advanced technological developments in various fields of mechanical engineering. Projects and design will be emphasized.
3 credits. Prerequisite: ME faculty permission and graduate standing

ME 499 Thesis/Project
Master's candidates are required to conduct, under the guidance of a faculty adviser, an original investigation of a problem in mechanical engineering, individually or in a group and to submit a written thesis describing the results of the work.
6 credits for full year

Engineering Sciences Courses

Undergraduate

ESC 000.1- 000.4 Engineering Professional Development Seminars The Engineering Professional Seminars and Workshops offer students an introduction to the profession of engineering as well as deal with their development as students. The Cooper Union's CONNECT program is an integral part of these courses and provides intensive training in effective communications skills. A wide range of topics is covered in addition to communications skills including ethics, environmental awareness, life-long learning, career development, conflict resolution, entrepreneurship, marketing, work-place issues, team dynamics, professional licensure and organizational psychology.
0 credits. Attendance required by all first and second year students. Pass/Fail grade based on attendance and participation

ESC 100 Engineering Mechanics
Equivalent system of forces, distributed forces; forces in structure; friction forces. Particle and rigid body mechanics; kinematics, kinetics. Newton's laws of motion; work and energy; impulse and momentum.
3 credits. Prerequisite: Ph 112

ESC 101 Mechanics of Materials
Introduction to solid mechanics; analysis of stress and deformation. Extension; flexure; torsion. Axisymmetric problems, beam theory elastic stability, yield and failure theory.
3 credits. Prerequisite: ESC 100

ESC 110 Materials Science
The objective of this course is to promote an understanding of the relationship between the molecular structure of a material and its physical properties. Topics include bonding in atoms and molecules, crystallinity, metals and alloys, polymers, mechanical properties of inorganic materials and composite materials.
3 credits

ESC 110.1 Materials Science for Chemical Engineers Understanding relationships among atomic or molecular structures, physical properties and performances of substances. Bonding, crystallinity, metals, alloys and polymers. Mechanical properties of inorganic and composite materials. Selection of materials for process equipment design, its effect on economics. Design concerning effect of corrosion and its prevention.
3 credits

ESC 120 Principles of Electrical Engineering Survey of Electrical Engineering for the non-major. Signal and circuit analysis, DC and AC circuits, transients, frequency response and filters, power systems. Additional topics may be covered as time permits.
3 credits. Prerequisite: Ma 113

ESC 121 Basic Principles of Electrical Engineering
Selection of topics from ESC 120. This class meets with ESC120 for the first ten (10) weeks.
2 credits. Prerequisite: Ma 113

ESC 130 Engineering Thermodynamics Rigorous development of the basic principles of classical thermodynamics. Zeroth, first and second laws of thermo-dynamics and their applications to open and closed systems. Analysis of thermodynamic processes, properties of real substances and thermodynamic diagrams.
3 credits

ESC 130.1 Chemical Engineering Thermodynamics First law of thermodynamics for closed systems; perfect gasses, 2- and 3-phase systems of one component; transient and steady state analyses using the first law of thermodynamics for open systems; second law of thermo-dynamics; introduction to concepts of entropy. Gibbs free energy and Helmholtz free energy; derivation and application of equations describing the auxiliiary thermodynamic functions and conditions of equilibrium in imperfect gasses.
3 credits. Prerequisites: Ch 160, ESC 170

ESC 140 Fluid Mechanics and Flow Systems Introductory concepts of fluid mechanics and fluid statics. Development and applications of differential forms of basic equations. Dynamics of inviscid and viscous fluids, flow measurement and dimensional analysis with applications in fluid dynamics. Friction loss and friction factor correlation; design of piping systems.
3 credits

ESC 141 Transport Phenomena
A unified approach to the rate processes involved in heat, mass and momentum transfer, including chemically reactive systems; reviews of generalized rate equation, mechanisms of transport processes; equations of continuity, motion and energy; applications to conduction, radiation, convective heat and mass transfer and diffusion; emphasis on the derivation of the applicable differential equations and methods of solving same for both laminar and turbulent flows; macroscopic balances for non-isothermal systems.
3 credits. Prerequisite: ESC 140

ESC 160 Systems Analysis
An introductory course in the basic concepts and techniques of systems analysis and optimization and their applications to the planning, design and managing of large-scale engineering systems. Topics include production functions, marginal analysis, linear and dynamic programming, decision analysis, project evaluation and selection, systems modeling and economic methods. Methodology is demonstrated through design projects.
3 credits

ESC 161 Systems Engineering
An introductory course to the mathematical modeling of systems. Topics include mechanical elements and systems, electric circuits and analogous systems, fluid elements and systems, analysis of systems using transfer functions, state space equations, analog simulation and digital simulation. Also covered are block diagrams, Laplace transforms, and linear system analysis. Computer projects will be assigned that will use MATLAB software.
3 credits

ESC 170 Material and Energy Balances Introduction to the analysis of chemical process systems, using material and energy conservation equations. Estimation of thermodynamics and thermochemical properties of real fluids for engineering calculations. Numerical methods and their implementation on the digital computer for solution of chemical engineering problems.
3 credits. Prerequisite: Ch 160

Interdisciplinary Engineering Courses

Undergraduate

EID 101 Engineering Design and Problem Solving Students work on cutting-edge, exploratory design projects in inter-disciplinary groups of 20 to 25. Each project has an industrial sponsor/partner who is available for student/faculty consultation and support. Oral and visual presentations as well as formal written reports are required for all projects. Professional competencies, team-work, human values and social concerns are stressed in the engineering design.
3 credits

EID 102 Introduction to Computer Science
This course has been renumbered: see CS 102.
3 credits

EID 103 Principles of Design
This course is designed to introduce students from all disciplines to the concepts of rational design. It is open to first-year students and sophomores. In the first part of the course students will learn by hands-on experience the importance of giving attention at the design stage to consideration of accessibility, repair, replacement, choice of materials, recycling, safety, etc. Students will develop the ability to make observations and record them in suitable form for further analysis of the design process. From this, concepts of “good” design will be developed, and students will be introduced to the formal design axioms and principles. This will lead to the second part of the course which will consist of a comprehensive, realistic design problem. Creativity, intuition and cultivation of engineering “common sense” will be fostered within the framework of design principles and axioms. The course will constitute a direct introduction to the disciplines in their interdisciplinary context.
3 credits. Prerequisite: EID 101

EID 105 Drawing and Sketching for Engineers (same as ME 105)
This course introduces engineering students to the fundamentals of free-hand drawing and sketching with an emphasis on the interpretation and communication of insights, concepts and dimensioned solutions. Drawings and sketches are often the first steps in innovative engineering solutions and invention. The primary goal of this course is to provide a comprehensive foundation in traditional drawing and sketching methods for engineers.
2 credits

EID 110 Engineering Design Graphics This course is for students who are well versed in basic AutoCAD and want to develop their 3D modeling skills plus learn how to customize the system. Course work includes writing custom AutoCAD menus and programs that are useful for the various engineering disciplines, using the Lisp programming language. Students will be given a number of 3D modeling assignments throughout the semester, building up to a final term project that utilizes their 3D modeling skills as well as their programming and customization knowledge.
3 credits. Prerequisite: permission of instructor

EID 111 Design, Illusion and Reality
There is much that we can do as engineers, artists and architects to restore the necessary constructive connection between humankind and nature. In this, a small but vital step is to see the design process in any branch of human activity as a whole and not as a matter of watertight compartments arbitrarily contrived. By taking a variety of particular examples from real situations, having known backgrounds in engineering, art and architecture, students get a glimpse of how the design processes are initiated and how the subsequent available options are resolved. The emphasis will be on the synthesis of, rather than the analytical approach to, problem solving.
1-3 credits

EID 112 Interactive Graphic Design
The course teaches usage of the web as a medium for publishing, exhibition, and communication. It familiarizes students with programming languages (HTML), Java Script, and graphic software (Photoship, Illustrator, Flash, and DreamWeaver). Besides the technical aspects, the coursse also introduces the basic artistic design principles, such as color, typography, composition, and layout. Furthermore, the practical issues of designing and organizing information for web communication will be discussed. Overall, students will develop proficiency in creatively and persuasively presenting information. Projects include assignments on individual programming languages and design principles. The main project is to construct a website for the presentation of a product or idea. The format of the class consists of lectures studio time, presentations, and critiques.
3 credits: 4 hours–NOTE: This course cannot be taken for credit as a technical elective by EE students

EID 121 Biotransport Phenomena
Engineering principles are used to mathematically model momentum, heat and mass transfer processes that occur in biological systems. After a general introduction to human anatomy and physiology, topics examined include blood rheology, circulatory system fluid dynamics, whole body heat transfer, vascular heat transfer, oxygen transport in tissue and blood, pharmacokinetics and the design of an artificial kidney (hemodialysis).
3 credits. Prerequisite: junior standing

EID 122 Biomaterials
A study of both natural and synthetic materials, especially those for orthopaedic applications. Mechanical properties, design considerations, bio-compatibility, potential for allergic response and carcinogenic ramifications, mechanical compatibility and effects of long-term implantation. Metallics, ceramics and polymers. Relative advantages and disadvantages of various materials. Materials for cardiovascular applications. Corrosion and chemical degradation.
3 credits. Prerequisite: permission of instructor

EID 123 Biosystems and Instrumentation Introduction to mathematical modeling and the formulation of analogs for biological systems. Electrical aspects of nerve signals, coupled with their analysis and measurement. Design and construction of electro-cardiographic systems. Computer analysis of electro-cardiograms. Applications of systems theory to various physiological subsystems including muscle response and pupillary-retinal response. Laboratory work required.
3 credits. Prerequisite: Superior grades or at least one course in control theory. Suggested for seniors only

EID 124 Bioengineering in Safety, Design and Injury Analysis and Prevention Accident reconstruction. Correlation between the events of an accident and injuries sustained. Analysis of sports injuries. Effects of seat belts/air bags in vehicular accidents. Analysis of injuries sustained by failure of equipment, medical devices, etc. Industrial and construction accidents. Special computational techniques to pinpoint product defects and reconstruct the chain of events leading up to and occurring during an accident.
3 credits. Prerequisite: ESC 100; co-requisite: ESC 110

EID 125 Biomechanics
An in-depth treatment of orthopaedic biomechanics, including freebody analysis applied to the musculoskeletal system, applied statics, dynamics and kinematics. Clinical problems relating to biomechanics. Lubrication theory applied to hard and soft tissues. Mechanical testing of tissue, including both static tests and dynamics tests. Tensor treatment of kinematic motions. Extensive reference to current literature. Muscle function, evaluation and testing. Exploration of the concepts of development of muscular power, work and fatigue.
3 credits. Prerequisites: ESC 100 and permission of instructor

EID 131 Energetics (same as ME 131)
3 credits. Prerequisite: ESC 130

EID 133 Air-Conditioning, Heating and Refrigeration (same as ME 133)
3 credits. Prerequisites: ESC 130, ESC 140

EID 140 Environmental Systems Engineering (Same as CE 141)
3 credits. Prerequisite: permission of instructor

EID 141 Air Pollution Control Systems System design for particulate, gas and vapor recovery. Study of dynamics of particulate behavior in fluid stream, Brownian motion, interception, inertial impact; target geometry and effects, nucleation and particle growth; energy consumption and collection efficiency. Diffusional operations studies, transfer unit requirements. Kinetics of diffusion in gas-gas, gas-liquid, gas-solid and gas-extended surface systems. Unsteady-state behavior, surface renewal; wave-front analysis. Effect of fluid dynamics. Energy consumption related to transfer units. Fundamentals of mechanisms in real systems. Design problems.
3 credits

EID 142 Water Resources Engineering (same as CE 142)
4.5 credits (3 hours of lecture, 3 hours of laboratory). Prerequisite: ESC 140

EID 153 Mechatronics (same as ME 153)

EID 160 Acoustics, Noise and Vibration Control Interdisciplinary overview of acoustics and its applications in industrial and environmental noise control, acoustics of buildings, vibration systems and control. Topics include: sound levels, decibels and directivity, hearing, hearing loss and psychological effect of noise, noise control criteria and regulations, instrumentation, source of noise, room acoustics, acoustics of walls, enclosures and barriers, acoustics materials and structures, vibration control systems; design projects.
3 credits. Prerequisite: permission of instructor

EID 165 (same as ME 165) Sound and Space Basics of acoustics, including sound waves, room and hall acoustics and metrics of sound. Audio engineering, including microphones, signal processors, amplifiers and loudspeakers. Skills and techniques using Pro Tools brand audio editor system to create original sonic and musical compositions. Public exhibition of an electronic music program.
3 credits. Prerequisite: permission of instructor

EID 170 Engineering Economy
Comparison of alternatives in monetary terms; meaning and use of interest rates; results evaluation including intangibles; risk in alternatives; principles underlying the determination of economic life; depreciation and depreciation accounting; financing business ventures; financial statement analysis; replacement of capital assets.
3 credits. Prerequisite: Ma 113

EID 176 Legal and Ethical Aspects of Engineering A survey of the courts and their jurisdiction; civil and criminal law; equity jurisprudence; expert witness, contracts and the importance of business law to the engineer. Other topics include patents, trademarks and copyrights; product liability; unfair competition; professional ethics and professional advancement.
3 credits

EID 300 Special Research Project
Students will work on individual projects in engineering under supervision of faculty. Problems will vary according to individual interest. Permission to register is required from the Office of the Dean of Engineering. Students on academic probation are ineligible for registration.
3–6 credits

EID 311 Production Automation
Concepts and principles of automated production lines; analysis of high volume, discrete parts production systems in metal working industry; partial automation; mechanized assembly systems. Features of numerically controlled machine tools, NC part programming, control loops of NC systems, computerized numerical control, adaptive control system, group technology, flexible manufacturing systems, application of manufacturing engineering principles to optimize manufacturing process flow. Student projects with emphasis upon design and application.
3 credits. Prerequisite: CS 102

EID 312 Manufacturing Engineering (same as ME 312)
3 credits. Prerequisite: EID 101

EID 313 Science of Material for Engineering Design (same as ME 313)
3 credits. Prerequisite: ESC 110 or ESC 110.1

EID 314 Introduction to Composite Materials (same as ME 314)
Composite materials are becoming increasingly important to engineering applications in mechanical, aerospace and civil engineering. This new course offers both basic principles and some general applications for composite materials and structures. The knowledge students acquired from this course will prepare them for both advanced graduate study and practical engineering practice in industry. In this course a design project will also be assigned so that the students can use what they have learnt in the course to design a pressure vessel using laminated composite materials for optimal strength of the structure.
3 credits. Prerequisites: ESC 101; ESC 110 or ESC 110.1

EID 320 Special Topics in Bioengineering Seminars on topics of current interest in biotechnology.
3 credits. Prerequisites: a basic understanding of engineering mechanics and materials; permission of instructor. May be repeated

EID 325 Science and Application of Bioengineering Technology
The overall purpose of the course is to provide the student with a general overview of the scope of bio-engineering. The major areas in the course are design in biomedical engineering, tissue engineering, medical imaging, cardiovascular, vision, rehabilitation, masculaskeletal system, robotic surgery and medical business.
3 credits. Prerequisites: permission of instructor

EID 326 Ergonomics
Principles of human-machine interactions with emphasis on the design of the workplace/machine, for maximum output or minimum risk to the operator. Mechanics of injury; case studies.
3 credits. Prerequisite: EID 120

EID 327 Tissue Engineering
Tissue Engineering involves the application of engineering and the life sciences to gain a fundamental understanding of structure-function relationships in normal and pathological tissues and the development of biological substitutes to restore, maintain or improve tissue functions. This course will provide an introduction to the science, methods and applications of tissue engineering. Topics include quantitative cell biology, tissue characterization, engineering design and clinical implementation.
3 credits. Prerequisites: working knowledge of engineering fundamentals, senior standing or instructor approval

EID 330 Introduction to Neurophysiology and the Biophysics of Neural Computation (Same as Ph 330)
3 credits

EID 333 Renewable Energy Technologies This course is designed as an introduction to renewable energy technologies, with special focus on wind energy, kinetic hydropower and solar energy. The course will address both the current technological status and the commercialization challenges facing each sector, including licensing, deployment, distribution and economic feasibility issues. Guest lectures by industry experts and field trips to various technology sites are planned. The course is open to all engineering juniors and seniors.
3 credis

EID 334 Combustion (same as ME 334)
3 credits. Prerequisite: ESC 141 or ME 142

EID 352 Advanced Control Theory (same as ME 352)
3 credits. Prerequisite: ME 151, ECE 121 or ChE 152

EID 353 Transducers, sensors and computer interfacing (same as ME 353)
3 credits. Prerequisite: permission of the instructor

EID 356 Digital Control and Non-linear Control (same as ME 356)
3 credits. Prerequisite: ME 151

EID 357 Sustainable Engineering and Development Sustainable engineering is examined, starting with an analysis of resources, (materials, energy, water) upon which manufacturing is based. Each resource is critically examined in terms of its availability and form and the ultimate impact of its usage on the state of the planet. A comparison of the design and construction of contemporary and primitive structure is used to illustrate the differences between the required infrastructure and environmental footprint, leading to a definition of "green" design. The technologies required to support contemporary lifestyles in the developed and the developing world are discussed within the context of manufacturing techniques, usage of natural resources and the generation of waste. Workshops, guest lectures and a term project incorporating the concepts of minimalism, materials usage, and aesthetic design are used to present students with a unique perspective engineering.
3 credits. Prerequisite: permission of instructor

EID 362 Interdisciplinary Senior Project I Individual or group design projects in interdisciplinary areas of engineering. These projects are based on the interest of the students and must have the approval of their adviser(s) and course instructor. Periodic and final engineering reports and formal presentations are required for all projects. In addition to technical aspects projects must also address some of the following: economic feasibility environmental impact social impact, ethics, reliability and safety.
3 or 4 credits. Prerequisite: students are required to have completed necessary preparatory engineering courses related to the project topic*

EID 363 Interdisciplinary Senior Project II Continuation of EID 362
3 or 4 credits. Prerequisite: EID 362*

EID 364 Interdisciplinary Engineering Research Problem
An elective course, available to qualified upper division students. Students may approach a faculty mentor and apply to carry out independent or group projects in interdisciplinary fields.
3 credits. Prerequisites: Permission of adviser(s)

EID 365 Engineering and Entrepreneurship Students will learn the fundamentals of being an entrepreneur and operating a successful business. From its original idea to the open market, students will choose an engineering related project or service and learn the principles of accounting, marketing, managing, financing, and continuing research. Students are required to choose their own service or product and write a business plan as their final project. Lectures include case studies on the various projects and guest speakers from the industry. Readings include articles from journals and textbooks.
3 credits

EID 370 Engineering Management
An exploration of the theories and techniques of management beginning with the classical models of management and continuing through to Japanese and American contemporary models. The course is specifically directed to those circumstances and techniques appropriate to the management of engineering. Lecture, discussion and case studies will be used.
3 credits

EID 371 Operations Management
An in-depth exploration of specific problems and techniques applicable to the management of production and large operating systems (e.g., engineering projects). The specific problems of demand analysis, capacity planning, production and inventory planning as well as scheduling and progress control will be presented. In addition, the concepts of total quality management, material requirements planning and statistical quality control will be presented. The presentation will include lectures and case problems.
3 credits. Prerequisite: EID 370

EID 372 Global Perspectives in Technology Management
Current global political, social and economic developments and future trends as they relate to technology management are discussed. Students learn to address issues of international technology transfer, multinational sourcing, quality control, diverse staff management, environmental considerations, etc. Working in teams on case studies and projects, students learn to conduct international negotiations and develop solutions to complex business problems. Special emphasis is placed on team cooperation and personal leadership. Oral presentations and written reports are required.
3 credits. Prerequisite: permission of ME faculty required

EID 373 Patent Law
In this course a student will study patent law in detail: the requirements for obtaining a patent ("utility, novelty and non-obviousness"); "trade secrets" as an alternative to patent protection; computer software and "business methods" as patentable subject matter. The class will focus on the theoretical (patent cases from the U.S. Supreme Court and the Federal Court, the patent statute, 35 U.S.C.) and the practical (analysis of issued patents; individual and group exercises in drafting and critiquing patent claims, familiarity with the Manual of Patent Examining Procedure). The course is open to juniors, seniors, graduate students and faculty.
3 credits. Prerequisite: permission of instructor

EID 374 Business Economics
In this course, the class will carry out a real-time forecast of the U.S. economy and explore its implications for the bond and stock markets. The course will build upon principles of both macro- and micro-economics. It will provide an introduction to the work done by business economists and the techniques they use. Students will become familiar with the database looking for relationships between key economic variables, and studying movements in interest rates over the period 1960-present. The class will be divided into teams of two students with each team choosing a particular aspect of the economy to forecast. The class will also work with various leading indicators of economic activity and will prepare forecasts of the key components of gross domestic product and other important variables. A formal presentation of the economic with invited guests from the Wall Street investment world will take place. To put forecasting exercise in context, there will be class discussions of business cycles, credit cycles, long waves in inflation and interest rates and the impact of the Internet on the economy and the stock market.
3 credits. Prerequisites: either S 334, S 347, or, EID 170, or, permission of the instructor

CE 380 Fundamentals of Construction Management (same as CE 380)
Introduction to the construction industry, Discussion of construction management, scheduling, estimating, contracts, equipment selection and cost, Building materials and methods, latest developments in technology.
3 credits. Prerequisite: permission of instructor

Graduate

EID 410 Materials and Manufacturing Processes (same as ME 410)
3 credits

EID 414 Solid Waste Management (same as CE 414)
3 credits. Prerequisite: permission of instructor

E1D 420 Axiomatic Design (same as ME 420)
An interdisciplinary design course open to graduates and senior undergraduates. Axiomatic design theory and methodology provide a systematic and scientific basis for making design decisions. Axioms, corollaries and theorems give designers a firm basis for conceptualizing design issues, eliminating bad design ideas during the conceptual stage, choosing the best design among those proposed and improving designs. The Independence Axiom and its implications together with the Information Axiom and its implications form the foundation of this approach. Basic concepts and methodologies will be illustrated by case studies taken from many different fields. Project required.
3 credits. Prerequisite: permission of instructor

EID 421 Rehabilitation Engineering (same as ME 421) Rehabilitation engineering is the application of engineering principles, technical expertise and design methodology in the development and provision of assistive technology, to help a person with a disability achieve his/her goals. Topics include the design of rehabilitation devices, human factors, client assessment, workplace assessment, high- and low-tech assistive devices and alternative and augmentative communication devices. Students will conduct research and design and lubricate custom assistive devices. Interdisciplinary teams will be encouraged.
3 credits. Prerequisite: permission of instructor

EID 422/CE 422 Finite Element Methods Shape functions and generalized displacements. Assemblage of elements, Convergence criteria. Triangular, rectangular and quadrilateral elements in plane stress and strain. Isoparamentric formulations. General Solids. Hexahedral and tetrahedral elements. Flexure in plates. General solids. Natural Coordinates. Special applications in blast mitigation design. Computer codes.
3 credits. Prerequisite: CE 122 or ME 100

EID 423 Measurement of Human Performance (same as ME 423)
Application of advanced engineering principles to the design of systems to evaluate muscle groups for strength, endurance and range of motion. Topics include isometric, isokinetic and sensibility testing; biofeedback, and strategies to minimize 'faking." Students will conduct intensive research and design and fabricate a device to evaluate a single muscle group. Interdisciplinary teams will be encouraged.
3 credits. Prerequisite: permission of instructor

EID 424 Bioengineering Applications in Sports Medicine
Application of engineering principles to athletic performance and injury. Topics include athletic training; mechanical causes of sport injuries; methods of injury prevention; design of protective and prophylactic sport devices; proper application of wound dressing, taping and bandaging; first aid for musculoskeletal sports injuries and healing and rehabilitation. Students will work in teams on case studies and projects.
3 credits. Prerequisite: permission of instructor

EID 425 Product Design I (same as ME 425)
An interdisciplinary design project course open to graduate and senior students. Students will work in small teams to design and build engineered solution to real-world problems. This is an advanced product development class to initiate students to industrial practice.
3 credits

EID 426 Product Design II (same as ME 426)
(continuation of ME/EID 425)
3 credits. Prerequisite: ME/EID 425

EID 430 Thermodynamics of Special Systems (same as ChE 430 and ME 430)
Thermodynamic analyses of solid systems undergoing elastic strain and of magnetic, electric and biological systems. Equations of state for these and other fluid and non-fluid systems. Thermodynamics of low temperature systems. Recent advances in obtaining real fluid and solid properties.
3 credits. Prerequisite: ChE 131 or ME 130

EID 435 GeoEnvironmental Engineering (same as CE 435)
Discussion of pertinent regulations and regulatory programs relevant to contaminated soil. Identification and characterization of contaminated soils, discussion of current treatment technologies both ex-situ and in-situ. Geotechnical design of waste facilities, the closure and improvement of waste facilities and construction on waste Utilization of waste for engineering purposes, the reuse and recycling of contaminated soil.
3 credits. Prerequisites: ESC 140, CE 141, CE 131 and permission of instructor

EID 438 Industrial Waste Treatment Design (same as CE 440)
3 credits. Prerequisite: permission of instructor

EID 439 Water and Wastewater Technology (same as CE 441)
3 credits. Prerequisite: permission of instructor

EID 440 Advanced Fluid Mechanics (same as ChE 440 and ME 440)
Introduction to multi-dimensional steady and unsteady compressible flow, velocity distribution, velocity potential and stream function. Turbulent flow. Boundary layer theory. Supersonic flows.
3 credits. Prerequisites: ESC 140 and permission of instructor

EID 441 Advanced Heat and Mass Transfer (same as ChE 441)
Principles of heat and mass transfer are used to solve various engineering problems. Topics studied include analytical and numerical solution techniques for steady and unsteady conduction processes, boundary layer flow, re-circulation phenomena, turbulent flow, radiation heat transfer, combined convection and radiation, diffusion mass transfer and chemically reacting systems.
3 credits. Prerequisite: ESC 141

EID 446 Pollution Prevention of Minimization (same as CE 446)
3 credits. Prerequisite: permission of instructor

EID 448 Environmental and Sanitary Engineering (same as CE 448)
3 credits. Prerequisite: permission of instructor

EID 449 Hazardous Waste Management (same as CE 449)
3 credits. Prerequisite: permission of instructor

EID 452 Principles of Interactive Computer Graphics
Point plotting, line drawing and raster graphics techniques. Two-dimensional transformations, clipping and windowing, graphical input devices and techniques. Graphics data structures and display lists. Principles of three-dimensional representation and solid modeling concepts. Specialized computer architectures for graphics. User interface design. Each student will undertake a design project to realize some aspect of the course material, related to his or her area of specialization. (This course will be limited to 8 students.)
3 credits. Prerequisite: ECE 161

EID 453 Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) (same as ME 453)
3 credits. Prerequisite: ECE 161

EID 455 Optimal Estimation Methods (same as ME 455)
3 credits. Prerequisite: ME 151 or ECE 121 or ChE 152

EID 457 Optimization Techniques For Design (same as ME 457)
3 credits. Prerequisite: Ma 223

EID 458 Industrial Robots (same as ME 458)
3 credits. Prerequisite: ME 312

EID 464 Computer-Integrated Manufacturing (same as ME 464)
3 credits. Prerequisite: ME 312

EID 470/CE 470 Urban Security
Design of urban systems to protect against terrorism. Analysis of blast loads. Blast mitigation design considerations. Technology transfer; military/defense to civilian sector. Response spectra. Pressure/impulse diagrams. Stand off distances. Blast mitigation measures for buildings, bridges and tunnels. Prevention of progressive collapse in tall buildings. Design of glazing. Retrofit upgrade of existing urban infrastructure. Building code and insurance issues.
3 credits. Prerequisites: CE 122 or ME 101 and permission of instructor

EID 480 Challenges Facing Engineering Start-ups in Innovative Technologies This course will address the various issues facing engineering start-ups in innovative technologies such as urban security engineering businesses, distributed electric generators, bio-medical engineering businesses. Topics include definition of mission and core values, business plans financing strategies, marketing considerations, intellectual property issues, employee relations and regulatory hurdles. The course will feature guest speakers with first-hand experience in relevant start-ups.
3 credits. Prerequisite: Open to seniors and graduate students

EID 481 Environmental Economics
How environmental regulations affect economic growth. Analytical framework and tools: valuing the environment for decision making; marginal damage function and marginal abatement cost: risk assessment; alternatives assessment; cost-benefit analysis; cost-effectiveness; distributive equity; precautionary principle. Issues relating to air, water, energy and materials. Environmental health issues. Creation of markets for new technologies.
3 credits

Biology

Bio 101 Molecular and Cellular Biology This course will examine in depth the genetics, molecular and cellular biology, pathology, toxins, microbiology and environment as they relate to humans and disease using organ-based or systems biology approaches (e.g., gastrointestinal, pulmonary, cardiovascular, urinary, endocrine, etc.) Major assignments will be individualized to student interests and majors when possible. As such, this course will provide the biological fundamentals for further study in biotransport, biocheminstry,
3 credits. Prerequisites: Ch 110 and Ch 160, or permission of instructor

Bio 102 Cell Biology
This course will provide human biology fundamentals to springboard into research projects at the intersection of biology and engineering. Topics will include anatomy and physiology of musculoskeletal and other major organ systems not covered in Bio 101, imaging modalities, concepts behind diagnostic and therapeutic surgical procedures and their limitations
3 credits. Sophomore standing preferred, but freshmen with AP Biology welcome

Chemistry Courses

Undergraduate

Ch 110 General Chemistry
An introduction to the general scientific principles associated with chemistry. This course will deal with fundamental ideas such as the concept of the atom, the molecule, the mole and their applications to chemical problems. The classical topics include: dimensional analysis and significant figures; atomic weights; periodic properties; chemical reactions and stoichiometry; redox reactions; ideal gas law and real gas equations of state; the liquid state and intermolecular forces; solution concentrations; chemical equilibrium and equilibrium constants; acids and bases; solubility equilibria; nomenclature of inorganic and organic compounds. The topics for atomic and molecular properties include: atomic structure and the quantum theory; electronic structure of atoms; the covalent bond and bond properties; molecular geometries and hybridization; molecular orbital theory.
3 credits

Ch 111 General Chemistry Laboratory Methods of quantitative analysis are used to explore chemical reactions and analyze unknowns. Modern chemical instrumentation as well as “classic” wet chemistry analytical techniques are covered. Statistical analysis of the experimental data is used to analyze results. Chemical laboratory safety and industrial chemical regulations are covered, as are the fundamentals of writing a technical report.
1.5 credits. Prerequisite: Ch 110; co-requisite Ch 160

Ch 160 Physical Principles of Chemistry The study of physicochemical properties will be extended and advanced. The laws of thermodynamics, which involve energy, enthalpy, entropy and free energy concepts, will be applied to chemical systems. Other topics include: vapor pressures and colligative properties of solutions; the phase rule; kinetics of homogeneous reactions; electrolytic conductance and electrochemistry.
3 credits. Prerequisite: Ch 110; co-requisite: Ch 111

Ch 231 Organic Chemistry I
Bond types and strengths, structural theory, bond angles and hybrid bonds; covalent bonds, polarity of bonds and molecules; dipole moments; molal refraction; melting points and boiling points relative to properties and natures of molecules; solubilities based on structures; functional groups; critical temperature, pressure and volume as a function of structure and functional groups, prediction of vapor pressure curves, latent heats. Nomenclature isomers and properties. Resonance and delocalization of charge phenomena; acidity and basicity (Lewis concept).
3 credits. Prerequisite: Ch 160

Ch 232 Organic Chemistry II
Extension of Ch 231 to systematic study of aliphatic and aromatic compounds, with emphasis on functional behavior and interpretation of mechanisms and bond types, polyfunctional compounds, carbohydrates and heterocyclic compounds.
2 credits (2 lecture hours). Prerequisite: Ch 231; co-requisite Ch 233

Ch 233 Organic Chemistry Laboratory Laboratory work will cover subject matter studied in Ch 231 and Ch 232, including synthesis and type reactions and identification of organic compounds.
2 credits (4 laboratory hours) Prerequisite: Ch 231

Ch 251 Instrumental Analysis Laboratory Fundamental principles of instrumental methods will be covered, including laboratory applications and limitations in scientific research. Specific methods include electrometric, such as polarography, electro-gravimetry and potentiometry; optical (such as visible and ultraviolet absorption), spectroscopy, emission spectroscopy and infrared spectroscopy; and other techniques such as chromatography and mass spectroscopy shall be included.
2 credits (4 laboratory hours). Prerequisite: Ch 160

Ch 261 Physical Chemistry I
With an emphasis on the basic theoretical justifications underlying observed physical phenomena, quantum mechanics will be developed and applied to the study of chemical systems with an emphasis on interpreting spectroscopic data. Modern methods of computational molecular modeling are introduced. Statistical mechanics is introduced as a link between quantum mechanics and thermodynamics.
3 credits. Prerequisites: Ch 160 and Ph 214

Ch 262 Physical Chemistry II
Continuation of Ch 261 with emphasis on electrochemistry, chemical kinetics and solid state chemistry. Selected topics.
2 credits. Prerequisite: Ch 261

Ch 333 Advanced Organic Chemistry Modern areas of organic chemistry, including synthesis, structure determination, stereo-chemistry and conformational analysis, reaction mechanisms, photochemistry, conservation of orbital symmetry, molecular rearrangements and other selected topics. Advanced laboratory studies in research problem form. Typical problems would involve studies of the synthesis, structure and properties of organic compounds, utilizing modern instrumental techniques. Independent laboratory work may be arranged.
3 credits. (2 hours of lecture; 4 hours of Laboratory). Prerequisite: Ch 232

Ch 334 Physical Organic Chemistry
Molecular orbital theory in organic chemistry, orbital symmetry and stereoelectronic selection rules, rate theory, kinetic isotope effects, carbonium ions and rearrangements, acid-base catalysis, quantitative correlations of reactivity and other selected topics.
3 credits. Prerequisites: Ch 232, Ch 261

Ch 340 Biochemistry
This course in the fundamentals of biochemistry will cover the following: Chemistry of carbohydrates, lipids, amino acids, proteins, and nucleotides; bioenergetics; kinetics and mechanisms of enzymes; and an introduction to molecular genetics, and biochemical dynamics of DNA and RNA.
3 credits. Prerequisites: Bio 101, Ch 231

Ch 363 Advanced Physical Chemistry Modern applications of physical chemistry and chemical physics are developed. Topics covered include: Quantum and classical statistical mechanics, phase space, and fluctuations. Intermolecular forces and their experimental/theoretical determination. Computational molecular modeling, including ab initio, semiempirical and molecular mechanics predictions of molecular properties, as well as Monte Carlo and molecular dynamics methods. Some projects will require computer programming. Applications to liquids, nanoclusters, polymers, surface adsorbates and biomolecules are considered. Guest speakers from academia and industry are invited to share their perspectives.
3 credits. Prerequisites: Ch 261, Ch 262 (or by permission from instructor)

Ch 364 Solid-State Chemistry
Solid-state reactions; nucleation and diffusion theory; thin films of elements and compounds; current topics.
3 credits. Prerequisite: Ch 262

Ch 365 Chemical Kinetics
Fundamental study of chemical reaction systems in gaseous and condensed phases; absolute rate theory; collision theory; energetics from molecular and macroscopic viewpoints. Experimental rate techniques, interpretation of experimental data. Reaction mechanisms and models for complex and elementary reactions. Homogeneous and surface catalysis; enzyme-controlled reaction rates.
3 credits. Prerequisite: Ch 262

Ch 370 Inorganic Chemistry
The vast and fascinating chemistry of inorganic compounds and materials will be covered. Atomic structure and the periodic table; molecular symmetry and spectroscopy selection rules; coordination chemistry; ligand-field theory and other electrostatic bonding models; superacids; reaction mechanisms; organometallic chemistry; chemistry of the heavy elements; nuclear chemistry. Chemistry and physics of ionic and molecular solids; atomic and molecular clusters; chemisorption and physisorption of surface-bound species; cage compounds and catalysts; bioinorganic chemistry. A useful course for chemical engineers to extend their knowledge of inorganic chemistry beyond the content of Ch 110. Strongly recommended for students interested in graduate work in chemistry.
3 credits. Prerequisites: Ch 110, Ch 160, Ch 231, Ch 261

Ch 380 Selected Topics in Chemistry Study of topics related to specialized areas as well as advanced fundamentals.
2-6 credits. Chemistry faculty approval required

Ch 391 Research Problem I
An elective course available to any qualified and interested student irrespective of year or major. Students may approach a faculty member and apply to carry out independent research on problems of mutual interest, in pure or applied chemistry. Topics may range from the completely practical to the highly theoretical, and each student is encouraged to do creative work on his/her own with faculty guidance.
3 credits

Ch 392 to 398 Research Problem II to VIII This is intended to allow students to continue ongoing research.
3 credits each. Prerequisite: permission of research adviser and student's advisor(s)

Graduate

Ch 440 Biochemistry II (continuation of Ch 340)
Discussion of metabolism: Glycolysis, Glycogen Metabolism, Transport through membranes including ATP-Driven Active Transport and Ion Gradient-Driven Active Transport, Citric Acid Cycle, Electron Transport and Oxidative Phosphorylation, Lipid Metabolism including Fatty Acid Oxidation and Biosynthesis, Cholesterol Metabolism, Arachidonate Metabolism: Prostaglandins, Prostacyclins, Thromboxanes and Leukotrienes; DNA Repair and Recombination, Eukaryotic Gene Expression including Chromosome Structure, Genomic Organization, Control of Expression, Cell Differentiation.
3 credits. Prerequisite: Ch 340

Computer Science

CS 102 Introduction to Computer Science Introduction to Engineering Problem Solving using algorithms and their design. Logics and basic analysis techniques are explored using programming languages 'C', C++ and Java. Students will also master one or more significant engineering design packages such as MATLAB, AUTOCAD, MAPLE, MATHEMATICA etc. Projects will be assigned.
3 credits, no prerequisites

Mathematics Courses

Undergraduate

Ma 110 Introduction to Linear Algebra Vectors in two- and three-dimensions, vector algebra, inner product, cross product and applications. Analytic geometry in three dimensions: lines, planes, spheres. Matrix algebra; solution of system of linear equations, determinants, inverses.
2 credits

Ma 111 Calculus I
Functions; limit of functions, continuity. The derivative and its applications: curve sketching, maxima and minima, related rates, velocity and acceleration in one dimension; trigonometric, exponential, logarithmic and hyperbolic functions. Definite and indefinite integrals; area, the fundamental theorem, techniques of integration.
4 credits

Ma 113 Calculus II
Applications of definite integrals: area, volume, improper integrals, work, arc length, surface area, centroid. Polar coordinates. Parametric curves in two and three dimensions: velocity, speed and accelerations. Partial derivatives and the chain rule, properties of the gradient. Maxima and minima. Sequences and series: convergence of sequences and series, Taylor and Maclaurin series, power series.
4 credits. Prerequisite: Ma 111; Prerequisite or co-requisite: Ma 110

Ma 151.1 Mathematics in Art
This course deals with the period beginning with Pythagoras in ancient Greece and goes up to the present day. Topics include: Goedel's incompleteness theorem. Euclidean and non-Euclidean geometries, infinity, paradoxes, soap film experiments. Also discussed are black holes, the Big-Bang theory, relativity and quantum theory. The course is open to all Cooper Union students but is primarily oriented toward making the above-mentioned concepts comprehensive to those with very little mathematics in their background. Engineering students should see the Mathematics faculty and their adviser(s) for permission to take this course. The relatedness of seemingly distant fields (science, art, mathematics, music) is a central theme of the course.
3 credits

Ma 163-164 Calculus and Analytic Geometry I, II
Second year mathematics course for architecture students. Emphasis is on topics that involve the mathematical approach to geometrical and physical relationships and on basic concepts and applications of calculus of functions of one and two variables.
3 credits each semester. Cannot be used to satisfy any degree requirement in the School of Engineering

Ma 223 Vector Calculus
Double and triple integrals and their applications. Vector fields. Gradient, divergence and curl. Line and surface integrals. Theorems of Green, Gauss and Stokes. Path independence of line integrals.
2 credits. Prerequisite: Ma 110 and 113. Usually given in fall and spring semesters

Ma 224 Probability
Sample spaces. Random variables. Probability. Distribution and density functions. Expectation. Mean and variance. Moments and generating function. Central limit theorem.
2 credits. Prerequisite: Ma 113. Corequisite Ma 223. Usually given in both fall and spring semesters

Ma 224.1 Probability and Statistics
This course deals with sample spaces, random variables, probability. Distribution and density functions. Expectation. Mean and variance. Moments and generating function. Central limit theorem. Point estimation. Confidence intervals. Hypothesis tests. Chi-square. ANOA. Estimations, sampling theory.
3 credits. Prerequisites: Ma 113. Co-requisite Ma 223

Ma 240 Ordinary and Partial Differential Equations Ordinary differential equations of the first order. Linear equations of higher order with constant coefficients. Power series solutions. Laplace transformation. Fourier series. Partial differential equations: method of separations of variables, applications to vibration and heat flow.
3 credits. Prerequisite: Ma 113

Ma 326 Linear Algebra
Finite-dimensional vector spaces. Linear independence. Dimension. Basis. Subspaces. Inner product. Matrices. Rank. Determinant. Systems of linear equations. Matrix algebra. Coordinate transformation. Orthogonal matrices. Linear transformation. Eigenvalues and eigenvectors. Quadratic forms. Canonical form.
3 credits. Prerequisite: Ma 223

Ma 336 Statistics
Statistical central limit theorem. Decision theory. Estimation: properties of estimators, point estimation, confidence intervals. Hypothesis testing: simple and composite hypothesis, Neyman-Pearson lemma, sequential methods, relationship to estimation. Normal distribution tests: t-test, chi-square, F-test. Introduction to non-parametric methods, regression and analysis of variance.
3 credits. Prerequisites: Ma 223 and Ma 224

Ma 337 Operations Research
Linear programming, simplex method, graphs and network theory, dynamic programming, game theory, queues, variational techniques, duality, Markov chains, Monte Carlo simulation, decision theory. Special topics depending on student interest, possibly including language questions, integer programming, nonlinear programming and topics from mathematical biology, econometrics and other applications of mathematics to the sciences and social sciences.
3 credits. Prerequisite: Ma 224

Ma 341 Differential Geometry
Theory of curves and surfaces, curvature, torsion, mean and Gaussian curvatures length, area, geodesics, 1st and 2nd quadratic forms, conformal mapping, minimal surfaces, tensor formulation and applications.
3 credits. Prerequisite: Ma 223 and permission of instructor

Ma 344 Tensor Analysis
Tensor algebra, covariant and contravariant tensors, metric tensors, Christoffel symbols and applications.
3 credits. Prerequisite: Ma 326

Ma 345 Functions of a Complex Variable Topological properties of complex plane, complex analytic functions, Cauchy-Riemann equations, line integrals, Cauchy's integral theorem and formula. Taylor series, uniform convergence, residues, analytic continuation, conformal mappings and applications.
3 credits. Prerequisite: Ma 223

Ma 347 Modern Algebra
Sets and mappings, the integers: well ordering, induction residue class arithmetic, Euler-Fermat theorems. Permutation groups: cyclic decompositions. transpositions, conjugate classes of permutations. Abstract groups: morphisms, subgroups, cyclic groups, coset decompositions. Factor and isomorphism theorems. Direct products of groups. Sylow's theorems.
3 credits. Prerequisite: Ma 326

Ma 350 Advanced Calculus I
Sets and functions, topological properties of real line, continuity and uniform continuity, differentiability, mean value theorems, the Riemann-Stieltjes integral and Taylor's theorem.
4 credits. Prerequisite: Ma 223

Ma 351 Advanced Calculus II
Uniform convergence. Differentitation of transformations, inverse and implicit function theorems. Applications to geometry and analysis.
4 credits. Prerequisite: Ma 350

Ma 352 Discrete Mathematics
Relations. Mathematical structures. Number theory. Algorithms. Complexity of algorithms. Cryptology. Recurrence relations. Graph theory. A shortest-path algorithm. Planar graphs. Trees. A maximal flow algorithm. Finite-state automata. Languages and grammars. Turing machines. The Church-Turing thesis. Unsolvable problems.
3 credits. Prerequisite: Ma 110

Ma 370 Selected Topics In Mathematics This is a seminar course involving discussion of topics in pure or applied mathematics that will be chosen by mutual agreement between the students and the instructor. Students will work independently on projects that may be of special interest to them.
3 credits. Prerequisites: Ma 326 and permission of the mathematics faculty

Ma 381 Seminar Individual investigation of selected topics in pure or applied mathematics, centered on a subject to be agreed on between students and the faculty leader. Emphasis will be on training in independent reading of mathematical literature, oral presentations and group discussions of the theory and problems.
Credits and class hours to be determined by faculty on individual basis. Prerequisite: Ma 223

Ma 382 Seminar (continuation of Ma 381)
Credits to be determined by faculty on individual basis. Prerequisite: Ma 381

Ma 391 Research Problem 1
An elective course available to qualified upper division students. Students may approach a faculty member and apply to carry out independent research on problems of mutual interest in pure or applied mathematics. Each student is encouraged to do independent creative work with faculty guidance.
3 credits. Prerequisite: Ma 240 and permission of research advisor.

Ma 392 Research Problem 2 Continuation of Ma 391
This is intended to allow students to continue ongoing research.
3 credits. Prerequisite: Ma 391 and permission of research advisor

Graduate

Ma 401 Boundary Value Problems
Orthogonal polynomials, Fourier series; properties of Legendre polynomials and Bessel functions. Applications to the wave equation and the differential equations of heat transfer in several dimensions.
3 credits. Prerequisites: Ma 223, Ma 240

Ma 402 Numerical Analysis
Techniques for the solutions of ordinary and partial differential equations, the classical problems of linear algebra, integration and systems of nonlinear equations. Error analysis, convergence and stability theory. Course assignments will include use of computing facilities.
3 credits. Prerequisites: Ma 223, Ma 240

Ma 403 Special Topics in Applied Mathematics Introduction to the general theory of partial differential equations; existence and uniqueness of solutions; integral equations; computational techniques using finite-element and probabilistic methods. Other current topics in engineering may be included also.
3 credits. Prerequisites Ma 223, Ma 240

Ma 415 Wavelets and Multiresolution Imaging (same as ECE 415)
3 credits. Prerequisite: Permission of instructors. Taught by the faculties of mathematics and electrical engineering

Ma 417 Mathematics of Medical Imaging Mathematical basis for various medical imaging methods including CT, MRI, PET. Radon transform, tomography (recovery from projections), inverse problems, artifacts and noise. Mathematical physics of related topics such as wave propagation, signal generation and detection, quantum mechanics.
3 credits. Prerequisite: Ma 240, Ma 326, or permission of instructor

Ma 470 Selected Advanced Topics in Mathematics
Selected topics in Mathematics treated at an advanced level.
Credits to be determined by Mathematics faculty. Prerequisite: Ma 326 and permission of the faculty member

Physics Courses

Undergraduate

Ph 112 Physics I: Mechanics
Static equilibrium, kinematics, Newton's Law's, non-inertial frames of reference, system of particles, work and energy, linear and angular momentum, rigid body motion, conservation laws, oscillation.
4 credits

Ph 151 Optics: The Physical Basis of What Is Seen
This course is intended primarily for students in the Schools of Art and Architecture. It requires little mathematical background, but much interest in such questions as: Why are sunsets red? Why does colorless rain splatter dark on the pavement? How do one-way mirrors work? Topics will include light and color; mirrors, lenses and optical devices; reflection, refraction, absorption, emission, interference, diffraction and polarization of light; addition and subtraction of "color," the visual response of the eye. There also will be special topics based upon student interest. Emphasis will be on scientific concepts and their application to optical and visual phenomena.
3 credits. Cannot be used to satisfy any degree requirement in the School of Engineering

Ph 165 Concepts of Physics I
An introduction to physics with an emphasis on statics and dynamics.
2 credits. Prerequisites: Ma 160, CS 102; co-requisite: Ma 163. Cannot be used to satisfy any degree requirement in the School of Engineering

Ph 166 Concepts of Physics II (continuation of Ph 165)
Additional topics include optics, waves and an introduction to structural analysis.
2 credits. Prerequisite: Ph 165; co-requisite: Ma 164. Cannot be used to satisfy any degree requirement in the School of Engineering

Ph 213 Physics II: Electromagnetic Phenomena Oscillations; transverse and longitudinal waves. Electric fields; Gauss' Law; electric potential; capacitance; D.C. circuits; magnetic fields; Faraday's law; inductance; A.C. circuits; electromagnetic waves.
4 credits. Prerequisite: Ph 112

Ph 214 Physics III: Optics and Modern Physics
Geometric and physical optics. Special theory of relativity. The quantum theory of light. The quantum theory of matter. Atomic structure. Nuclear structure and radioactivity.
3 credits. Prerequisite: Ph 213

Ph 291 Introductory Physics Laboratory Physical measurements and analysis of experimental data. The experiments test and apply some basic principles selected from the following fields: mechanics, sound, electromagnetism, optics and modern physics. Experiments and topics may vary each semester. Digital and analog laboratory instruments; computer acquisition and analysis of data. Estimate of systematic and random error, propagation of error, interpretation of results. This course complements three lecture courses, Ph 112, Ph 213, Ph 214.
1.5 credits. Prerequisite: Ph 112; co-requisite: Ph 213

Ph 319 Introductory Quantum and Solid-State Physics
Wave-particle experiments, wave-particle duality. Formalism and interpretation of quantum mechanics. Schroedinger's equation; its solution for selected simple cases. Atomic, molecular and crystalline structure. Binding and energy bands in solids. Thermal, electrical and magnetic properties. Imperfections; semiconductors, lasers.
3 credits. Prerequisite: Ph 214

Ph 327 Topics in Modern Physics
Seminar course with student participation in several topics of current interest in experimental and theoretical science.
3 credits. Prerequisite: Ph 214

Ph 330/EID 330 Introduction to Neurophysiology and the Biophysics of Neural Computation
This course will introduce students to the fundamentals of neurophysiology through a combination of traditional classroom instruction and laboratories. Each topic covered will include a physiological introduction, laboratory exploration, physical/mathematical analysis and computer modeling. Topics include biophysics of single neurons (e.g. ion movement through cell membranes, generation of action potentials, synapses and neurotransmitters), Hodgkin-Huxley and other related models of neural excitability, signal detection and signal reconstruction and neural coding in sensory systems. In the laboratories, students will learn a variety of extracellular and intracellular experimental techniques using invertebrate preparations. The class will culminate with an independent project.
3 credits. Prerequisites: permission of instructor, Ph 213, Ph 214, Ph 291, Ma 240

Ph 328 Relativity and Electrodynamics Introduction to tensors; formulation of electromagnetic theory. Special and general theories of relativity. Topics include space-time transformations, electromagnetic stress- energy-momentum tensor, four-space curvature and gravitational field equations, description of basic experiments, gravitational waves, cosmological models.
3 credits. Prerequisite: Ph 214

Ph 360 Special Projects in Physics
Special projects in experimental or theoretical physics.
Credits and prerequisites determined in each case by the physics faculty

Ph 370 Introduction to Astronomy and Astrophysics A quantitative introduction to Astronomy and Astrophysics. Topics include: Introduction to observational Astrophysics. The Sun, "normal stars" and interacting binaries. Stellar evolution and energy generation. Supernovae, pulsars, white dwarfs, neutron stars, black holes. Star clusters. Galaxies, and interstellar medium, galaxy clusters. Quasars and Active Galactic Nuclei. Cosmology. Prior knowledge of astronomy not necessary.
3 credits. Prerequisites: permission of instructor

Graduate

Ph 429 Deterministic Chaos with Engineering Applications
A simple mathematical formalism explains how a nonlinear system with no random element may be intrinsically unpredictable even when its governing equations are known. The mathematics of chaos (including fractals) will be presented, with applications drawn from mechanical, biological, chemical processes; the weather; electric circuits; lasers; general relativity; models of war; the economy; the spread of epidemics, etc.
3 credits. Prerequisites: Ph 214, Ma 1l3 (Ma 240 preferred) and CS 102

Ph 462 Nuclear Physics
Historical introduction, relativity kinematics, basic nuclear properties, nuclear chain reactions, phenomenological nuclear models (shell, liquid drop and collective), equation of state (with computer exercises), an overview of particle physics, quantum chromodynamics, standard model, current research topics (neutron stars, big-bang nucleosynthesis, heavy-ion collider experiments)
3 credits. Prerequisites: permission of instructor, Ph 214, Ma 240

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