

# 10 • School of Engineering and Applied Science

## General Information

Engineers and applied scientists use the knowledge of mathematics, the sciences, and computer science to design and build physical devices, processes, structures, and systems that satisfy society's growing dependence on technology for health, safety, and prosperity. Today's graduates will spend their careers in an evolving global market filled with unprecedented challenges and opportunities. The School of Engineering and Applied Science therefore seeks to prepare and motivate its students to excel in their chosen endeavors by instilling in them the necessary attributes of knowledge, creativity, inquisitiveness, leadership, confidence, awareness, and ethical values.

Graduates must have a firm understanding of the fundamental principles of their discipline, the knowledge to design a system, component, or process to meet desired ends, and the ability to adapt innovative, ethical solutions to the problems of society. Because engineering and applied science graduates enjoy a broad range of career opportunities, it is also important that they understand research methods, have the ability to integrate broad interdisciplinary considerations, and have the confidence to pursue new professional activities. They must be capable of working in teams and leading them. In addition, they must be skilled in oral and written communication and in the use of computer tools and laboratory instruments appropriate to the discipline. Above all, they should acquire self-study habits in order to enjoy a rich, life-long learning experience.

While most graduates move directly into professional careers in industry and government, many others seek further academic preparation for careers as Ph.D. researchers or university faculty in engineering and applied science. Some use the degree to prepare for graduate programs in other areas, such as business, law, and medicine. The Office of the Dean welcomes inquiries, via phone or letter, from prospective applicants who have questions about career possibilities, program options, high school preparation, and other concerns.

## Engineering at Virginia

The University of Virginia takes pride in its continued development of modern engineering education and research. For over one hundred fifty years, the University has offered regular study in engineering, coinciding with the industrial development of the nation and paralleling the rise of the engineering profession itself.

The infusion of applied science into the learned professions was anticipated in the founding of the University. As early as 1825, the Rector and Visitors formally indicated that instruction in military and civil architecture would be a part of the education program of the University. Such courses were offered starting in 1827. Notable members of the early engineering staff were Charles Bonnycastle, trained in military engineering in England, and William Barton Rogers, later co-founder of the Massachusetts Institute of Technology. Engineering instruction was not sought widely by young men in the predominantly agricultural South, however; and by 1850, it was announced that the engineering program would be discontinued.

A new and more successful beginning was made in 1865 under the direction of Professor Charles Scott Venable, and by 1869 the University awarded its first degrees in engineering. Instruction was offered in civil and mining engineering until the 1881-1882 session, when engineering became a professional department. William Mynn Thornton became the first dean of Engineering in 1905. Under his leadership, three new degree programs were added: mechanical engineering in 1891, electrical engineering in 1897, and chemical engineering in 1908.

Between World War I and World War II, the engineering curricula were revised and strengthened to provide a broader program of studies, including the humanities. During both wars the school offered engineering instruction to members of the armed forces, and ROTC programs for the Navy, Army, and Air Force were introduced during and after World War II.

Reorganization following World War II led again to an extensive revision of all curricula and to the graduate studies now offered. In 1955, two new branches of engineering study were recognized by degrees: aeronautical and nuclear engineering. In the same year, the first doctoral programs were instituted in chemical engineering and in engineering physics.

In 1962, the name of the school was changed to the School of Engineering and Applied Science in anticipation of the establishment of the Department of Materials Science (1963), the Department of Applied Mathematics and Computer Science (1964), and the Department of Biomedical Engineering (1967). The Department of Systems Engineering was established in 1975, and in 1984, applied mathematics and computer science became separate departments. Further reorganization has led to the present school academic structure with its Departments of Bio-

medical Engineering; Chemical Engineering; Civil Engineering; Computer Science; Electrical and Computer Engineering; Materials Science and Engineering; Mechanical and Aerospace Engineering; Systems and Information Engineering; and the Division of Technology, Culture, and Communication.

The undergraduate program in engineering science and the graduate program in engineering physics are administered by the Department of Materials Science and Engineering.

## Address

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Thornton Hall  
University of Virginia  
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## Facilities and Services

The School of Engineering and Applied Science is located in a complex of buildings, the main one being Thornton Hall, named after the first dean of engineering. Thornton Hall houses the school's administrative offices, the Departments of Civil Engineering and Electrical Engineering; the Division of Technology, Culture, and Communication; and assorted research laboratories. South of Thornton Hall is Olsson Hall, which houses the Departments of Computer Science and Systems Engineering. Adjacent to these buildings are three buildings housing the Departments of Mechanical and Aerospace Engineering, Materials Science and Engineering, and Chemical Engineering. The Department of Biomedical Engineering is located in Stacey Hall, which is part of the Health Sciences Center. The Aerospace Research Laboratory is located on Mount Jefferson.

The Science and Engineering Library is located in Clark Hall. It includes books and bound journals, current scientific periodicals and technical serials, and files of graduate and undergraduate theses and dissertations. Reference service is available to all parts of the University, to other educational institutions, and to industry by the library staff and, occasionally, by others on the professional staff of the School of Engineering and Applied Science. Close cooperation is maintained with the other University libraries, whose total resources of more than four million volumes are open to engineering students and faculty members.

The Office of Minority Programs, established in the School of Engineering and Applied Science in 1986, is available to help

minority students by providing academic support, motivational activities, and financial assistance. The office provides counseling and other special services for both undergraduate and graduate students.

An Office of Career Services is available to help engineering students establish their career goals and develop strategies to achieve those objectives. The office provides resource material on career fields, job search strategies, interviewing techniques, and employment opportunities. It also coordinates on-Grounds interviews in conjunction with University Career Services, manages the Cooperative Education Program, and develops a broad range of summer job opportunities.

### Computers

The School of Engineering and Applied Science (SEAS), the Department of Information Technology and Communication (ITC), and the University Library provide a wide range of modern facilities and services to support student computing. Students use the facilities primarily for course work, projects, capstone design, and thesis research.

SEAS and the University invest heavily in computer labs and multimedia facilities for student use. Students, too, have been bringing their own computers in greater and greater numbers, although there is no computer ownership requirement. All dormitory rooms have been wired with network connections. For further information on personally owned machines, please see "Computers at U.Va.: a handbook for new students," available online at [www.itc.virginia.edu/itcweb/students/handbook/handbook.html](http://www.itc.virginia.edu/itcweb/students/handbook/handbook.html).

A high-speed network provides access to all areas of the University, as well as the Internet, while supporting public computing labs, which contain over 700 networked PCs and Macs with fully configured software. The labs, available to all students, are located throughout the Engineering School and other on-Grounds locations, including some University dormitory buildings. Public labs with UNIX supercomputers are also available.

These facilities are open 24 hours a day, seven days a week. Many are staffed with student consultants during the afternoons and evenings, while the help desk provides support by telephone (434/924-3731), e-mail ([consult@virginia.edu](mailto:consult@virginia.edu)), and in person (235 Wilson Hall) is also provided. In addition to this technical support, ITC offers numerous training workshops and short courses. Public labs provide free printing via high-speed laser printers, and other centralized services, including e-mail, disk storage, and web publishing are provided to all students.

Some classrooms at the Engineering School are technology-equipped and have computers at students' desks. These computers permit students to learn by working a problem in the classroom, individually or as part of a team, and facilitate interaction between faculty and students. There are over

100 computers located in classrooms of this type throughout the University, in addition to the training rooms, media labs, and other centers containing specialized equipment and services.

SEAS also maintains computer facilities, teaching labs, and design labs specifically for engineering and applied science students. These departmental labs contain over 250 PCs and Macs, and over 70 UNIX workstations and X-terminals. They provide access to discipline-specific software, high-end workstations, and a variety of peripheral devices. Specialized studios, such as our Internet Teaching Lab, allow hands-on experience with networking hardware, software, and related leading-edge technologies.

For more information about computing facilities and services, please visit <http://infotech.seas.virginia.edu>.

### Research and Development

The School of Engineering and Applied Science currently conducts a thriving and diversified \$35 million annual research program under the sponsorship of various federal agencies and private companies. Over 450 active research projects support faculty, professional researchers, and students. These projects span a variety of engineering disciplines and include biotechnology and nanotechnology microelectronics, advanced materials, biomedical engineering, information technology and environmental engineering. These programs provide an excellent opportunity for undergraduate and graduate training.

Under the School of Engineering and Applied Science, research has led to the creation of special laboratories in areas of particular interest, including the Aerospace Research Laboratory; Applied Electrophysics Laboratory; Injury Prevention Program; Center for Bioprocess Development; Communications, Control and Signal Processing Laboratory; Composite Mechanics Laboratory; Center for Advanced Computational Technology; Small Center for Computer Aided Engineering; Center for Electrochemical Science and Engineering; Center for High Temperature Composites; Intelligent Processing of Materials Laboratory; Internet Technology Innovation Center; Legion Meta-Computing Project; Light Aerospace Alloy and Structure Technology Program; Light Metals Center; Center for Magnetic Bearings; Mathematical-Computational Modeling Laboratory; Next-Generation Real-Time Systems Laboratory; Institute for Technology in Medicine; Networking Multimedia; Institute for Parallel Computation; Center for Risk Management of Engineering Systems; Rotating Machinery and Controls Industrial Program; Center for Semicustom Integrated Systems; Center for Survivable Information Systems; Center for Transportation Studies; Center for Engineering of Wound Prevention and Repair; Center for Genetic Engineering Tar-

geting Vascular Disease; Institute for Microelectronics; and the Virginia Laboratory for Engineering and Automated Design.

### Activities and Organizations

**Engineering Council** The Engineering Council serves as the student government within the School of Engineering and Applied Science. It is headed by a president, vice president, treasurer, and secretary and has representatives elected from each class and department. Members from Student Council, the Judiciary Committee, and the Executive Committee also have seats on the council.

The Engineering Council primarily serves as a liaison between students and faculty, coordinates student activities within the school, advises on matters of curricula, and promotes social activities.

### Student Branches of Professional Societies

Represented in the school are the American Institute of Aeronautics and Astronautics (AIAA); the American Institute of Chemical Engineers (AIChE); Alpha Chi Sigma (AXE); the American Society of Civil Engineers (ASCE); the Institute of Electrical and Electronics Engineers (IEEE); the American Society for Engineering Management (ASEM); the American Society of Heating Refrigeration and Air Conditioning Engineering (ASHRAE); the American Society of Mechanical Engineers (ASME); and the Association for Computing Machinery (ACM).

**Tau Beta Pi**, the national engineering honorary fraternity, recognizes high scholastic achievement and honorable character in engineering students.

**Note:** Active groups of other honorary fraternities include Chi Epsilon (civil engineering), Eta Kappa Nu (electrical engineering), Omega Rho (systems engineering), Pi Tau Sigma (mechanical engineering) and Sigma Gamma Tau (aerospace engineering).

### Theta Tau Professional Engineering

**Fraternity**, founded in 1904, is the University's only national, professional, engineering fraternity. Since its establishment at the University of Virginia in 1922, Theta Tau has been bringing its members closer together through social service and professional activities. Theta Tau is a coed fraternity that strives for a diverse and enthusiastic membership.

**Trigon Engineering Society** takes pride in its members being well-rounded engineers. Trigon sponsors numerous service projects each semester, takes part in intramural sports, and sponsors many social events. Membership in Trigon is open to any undergraduate in the Engineering School.

**The Omicron Xi Engineering Society**, founded on January 21, 1987, is a service and social organization dedicated to promoting brotherhood between the engineering disci-

plines and performing good works within the school, the University, and the community. The society builds upon the University tradition of meaningful social interaction, sponsoring events for the University community in addition to a variety of intra-society affairs.

**The Society of Women Engineers** is a non-profit, educational, professional service organization dedicated to communicating the need for women engineers and encouraging young women to consider an engineering education.

**The National Society of Black Engineer's (NSBE)** mission is to increase the number of culturally responsible African-American engineers who excel academically, succeed professionally and positively impact the community. UVA's Chapter is recognized nationally for its accomplishments which include an academic excellence program, tutorial programs, group-study sessions, technical seminars and workshops lead by professional engineers, and very active outreach programs. NSBE's Pre-College Initiative Program (PCI) is highly dedicated to encouraging and mentoring area youth in pursuit of higher education. Nationally, the NSBE organization has a communications network, two national magazines, a host of professional newsletters, and sponsors annual national conventions, conferences, and career fairs.

**The Society of Hispanic Professional Engineers (SHPE)** is the leading social-technical organization whose function is to achieve educational excellence, economic opportunity and social equity for Hispanics in engineering, math, and science. The SHPE chapter at UVA provides a network for Hispanic students to participate in regional and national conferences, technical seminars, and career fairs. SHPE members visit high schools and invite students on grounds to experience academic and social life at UVA in an effort to encourage them to pursue a higher education in engineering, math, or science.

### Honors, Awards, and Scholarships

**The Rodman Scholars Program**—named for Walter S. Rodman, dean of the School of Engineering and Applied Science from 1933 to 1946—is for talented, well-rounded students with a strong interest in the school's curricula. Rodman scholars are selected from the entering class on the basis of superior academic credentials and indications that the student can benefit from, and contribute to, the program; participation is by invitation only. Several courses have been set up for Rodman scholars—from physics, humanities, and design in the first year, to a special seminar in conjunction with the Rodman Eminent Scholars Series later in the

curriculum. During their first year, Rodman scholars live in a selected dormitory with Echols scholars from the College of Arts and Sciences.

**The Virginia Engineering Foundation Award** is made annually to a person who, in the opinion of the foundation, has been effective in completing a project of importance to the foundation and the school.

**The Mac Wade Award** is presented in memory of Freeman McMillan Wade, Class of 1952, who was killed in action in the Korean War. It is awarded annually to the group, faculty member, or student who has rendered outstanding service to the School of Engineering and Applied Science.

**Scholarships** There are no scholarships for which newly admitted students can apply. Students whose families qualify for financial aid are automatically considered for certain scholarships as part of their aid package.

A limited number of endowed merit-based scholarships are awarded to incoming Rodman scholars. Selections are made prior to the offer of admission to the University, and the award offers are extended at the time students are invited to join the Rodman Scholars Program. Prospective students do not apply for either the program or the scholarship.

Regardless of financial need status, enrolled students who can demonstrate satisfactory progress toward their degrees have the opportunity to apply for a number of industrial or endowed scholarships. These have specific restrictions, such as GPA, major field, academic level, intended area of employment, geographic location, and demonstrated leadership. The scholarships are publicized to the student body in early spring for submission to the committee after the spring recess, usually around the third week of March.

**Dean's List** Full-time students who demonstrate academic excellence while taking a minimum of 15 credits of graded course work are eligible for the Dean's List of Distinguished Students at the end of each semester. Courses taken on a CR/NC basis may not be counted toward the 15-credit minimum. A current minimum grade point average of 3.4 is necessary to be eligible for the dean's list. Any student receiving an F, NC, or NG during the semester is not eligible to be on the dean's list.

**Intermediate Honors** Students who enter the University directly from high school or preparatory school and who, after four regular semesters, have completed 60 graded credits of course work and are in the top twenty percent of their School or College class, are awarded a Certificate of Intermediate Honors. The notation "intermediate honors" is also placed on each student's official academic record. Beginning with the entering class of 2001, Intermediate Honors will

be awarded to students who enter the University directly from high school and who, after four regular semesters, have completed at least 60 credits of course work and are in the top twenty percent of their class. The computation is based upon the cumulative grade point average at the end of the fourth semester.

**Theses and Commencement Honors** Students who have demonstrated high academic achievement in pursuit of their bachelor's degree are eligible for commencement honors.

Diplomas inscribed "with distinction" are awarded to graduates who have earned a cumulative grade point average of at least 3.4.

Diplomas inscribed "with high distinction" are awarded to graduates who have earned a cumulative grade point average of at least 3.6.

Diplomas inscribed "with highest distinction" are awarded to graduates who have earned a cumulative grade point average of at least 3.8.

All students in the School of Engineering and Applied Science, whether or not they satisfy the requirements for commencement honors, are required to complete a senior thesis and take TCC 401 and 402, the six-credit thesis course.

## Degree Programs

### Admission

Inquiries regarding admission to the School of Engineering and Applied Science should be addressed to the Dean of Admissions, P.O. Box 400160, University of Virginia, Charlottesville, Virginia 22904-4160 or by e-mail at [undergrad-admission@virginia.edu](mailto:undergrad-admission@virginia.edu).

### Requirements

The first and second years of study at the engineering school are spent garnering a solid background in the sciences and mathematics. The student takes courses in chemistry, physics, computer programming, mathematics, and various courses in engineering science, as well as social science and humanities courses.

During the first year, students declare a major in one of ten programs in engineering or applied science. The last three years are spent specializing in a chosen area and taking further courses in the general field of engineering. Successful graduates can expect a wide range of career opportunities in engineering, business, law, and medicine.

In the event a particular major is oversubscribed, admission may be limited. Admission to such programs is based on space availability, academic performance, and extra-curricular activities. At present, systems engineering, computer engineering, and computer science are limited-admission programs.

**Bachelor's-Master's Program** Outstanding students may be admitted to the combined Bachelor's-Master's Program at the end of their third year. After admission, students take a mixture of graduate and undergraduate courses and work on a sponsored research project in the summer and academic year. The requirement of a senior thesis is waived, and the student writes a master's thesis to satisfy the requirement of both the undergraduate and graduate degrees. This program encourages the best and brightest students to enter into research in the various engineering and applied science fields.

**Graduate Degrees** are offered in all of the school's areas of specialization. For information on these programs and inquiries regarding admission, contact the Office of Graduate Programs, School of Engineering and Applied Science, Thornton Hall, University of Virginia, Charlottesville, Virginia 22903-2442.

**Admission As a Special Student** In certain circumstances, individuals may be permitted to enroll in a maximum of two School of Engineering and Applied Science courses through Continuing Education.

Special students who wish to become degree candidates must apply through the University Office of Admission for undergraduate admission or through the School of Engineering and Applied Science for graduate admission.

**Advisory System** Faculty members and upper class students in the School of Engineering and Applied Science aid entering students in the transition to college life and in furthering their academic and career interests. Each first-year student consults with his or her faculty advisor about course and major selection, and other academic requirements.

Toward the end of the second semester, the student selects a major field of engineering and is then assigned an advisor in the department administering the degree program. The departmental advisor helps the student plan a curriculum and serves as a counselor for other academic matters and career interests.

## Academic Rules and Regulations

Each student is expected to complete the undergraduate program in eight semesters (plus summers, if necessary). Exceptions may be made in certain cases.

Normal progress toward graduation consists of taking a minimum of 15 credits each semester and maintaining a cumulative grade point average of 2.0 or better. The minimum (15 credits) may not be satisfied with courses taken on a credit/no credit basis.

**Academic Probation** First-year students who receive a semester grade point average

below 1.8 are placed on academic probation. All other students who receive a semester grade point average below 2.0 are placed on academic probation.

**Academic Suspension** Students are placed on academic suspension from the School of Engineering and Applied Science when: they have been previously placed on academic probation, again receive a semester grade point average below 2.0 (1.8 for first-year students), and hold a cumulative GPA below 2.0.

A student on suspension may be readmitted after absence from the University for at least one academic year. Application for readmission must be made by letter addressed to the assistant dean for undergraduate programs. This letter should briefly describe the activities of the applicant since his or her suspension and his or her future academic goals.

**Expulsion** A student who returns from academic suspension, receives a semester grade point average below 2.0, and sustains a cumulative grade point average below 2.0 is expelled from the school. A student who fails a required course three times is also expelled from the School of Engineering and Applied Science.

**Appeal of Academic Regulations** In circumstances not covered by specific regulations, or in difficulties that cannot be resolved by the dean or the instructor concerned, a student has the right to petition the Committee on Rules and Courses for redress of his or her grievance. The action by the committee on the petition is final inasmuch as it acts for the full faculty in these matters.

The petition must be signed and dated by the student and submitted to the Office of the Assistant Dean for undergraduate programs. The petition must contain:

1. the name of the student's academic department (except first-year students);
2. a clear and concise statement of the variance requested;
3. adequate supporting evidence to enable the committee to render fair and proper judgment;
4. a signed acknowledgement by the student's academic advisor.

The petitioner will be notified by letter of the action taken by the Committee on Rules and Courses.

### Course Load

**Normal** The normal undergraduate course load is 15-18 graded credits, unless the student is on probation, in which case a course load of 12 to 15 credits is recommended. Any program of study requires the advisor's approval.

**Overload** An overload of 19 or 20 credits may be approved by a faculty advisor for a student who has achieved a grade point average of 3.0 or higher.

A proposed overload amounting to 21 or more credits must also be reviewed and approved by the Office of the Dean. Demonstrated superior academic performance and clear career planning will be the major criteria for approval, including a grade point average of 3.6 or higher.

**Underload** A semester load of fewer than 15 credits (not counting CR/NC courses) must be approved by the advisor and the dean's office.

**Attendance** Regular attendance in classes is a vital part of the educational process. At the University of Virginia, each student is expected to attend all lectures, laboratories, quizzes, and practical exercises, subject to absence penalties specified by the instructor.

Absences traditionally excused are those that occur because of illness or death in a student's family, important religious holidays, or authorized University activities, such as field trips or University sponsored events.

Students who anticipate absence for cause should obtain permission from the instructor in advance of the absence; unforeseen absences resulting from sickness or other circumstances considered to be emergencies may be excused by the instructor, and arrangements may be made with the instructor to complete the assignments missed.

Engineering and Applied Science students taking courses in the College or other schools of the University are governed by the attendance regulations of the instructor in that division; unexcused absences from such courses are subject to the penalties prescribed.

**Credit/No Credit Grades** Students have the option of receiving the grades CR (credit) or NC (no credit) in place of the regular grades, A through F. This option may be selected when students register for courses. Instructors have the right to deny students permission to take courses on a CR/NC basis. If this occurs, students may change back to the regular grading option or drop the courses entirely. Courses taken for CR/NC may not be used for any major or degree requirements. Only courses that are not part of the degree program may be taken CR/NC. The deadline for selecting the CR/NC option is the same as the drop deadline.

**Dropping a Course** With the approval of the student's advisor, a student may drop and void registration in a course any time up to the official drop date, unless such action reduces the number of credits for which the student is registered to fewer than 15. Normally, a student will not be permitted to take less than 15 credits a semester, not counting CR/NC courses. Permission to take less than 15 credits a semester must be obtained from the Office of the Dean.

**Withdrawing from a Course** After the drop date, a student must petition the Office

of the Dean to withdraw from a course. However, permission to do so is granted only when there are extenuating circumstances beyond a student's control, such as illness. A student who is permitted to withdraw from a particular course will receive a WP (withdraw passing) or WF (withdraw failing) for the course. Petitions must be signed by the course instructor and faculty advisor, and approved by the Office of the Dean.

**Extension of a Course** After the withdrawal date (two weeks before the end of the semester), a student can no longer withdraw from a course. If there are extenuating circumstances, and if it is feasible, a student may petition for a course extension. If approved, all work must be completed by the end of the next academic term and preferably before the start of the next term. Feasibility is determined after a review of the outstanding work, the availability of the instructor, the accessibility of laboratory facilities, and other practical considerations.

**Enforced Withdrawal From a Course** With the approval of the dean, faculty may impose enforced withdrawal with a grade of F as a penalty for habitual delinquency in class, habitual idleness, or any other fault that prevents the student from fulfilling the purposes implied by registration in the University.

Enforced withdrawal may also be imposed for failure to take the physical examination required of all entering students, or for failure to obtain medical leave or medical withdrawal from the Department of Student Health in the case of repeated or prolonged absence from class as a result of illness.

**Laboratory Courses** To register for or attend any laboratory course, a student must be registered or have credit for the associated lecture course. If the associated courses are taken concurrently and the lecture course is dropped, the laboratory course may be continued for credit only with permission of the laboratory instructor or the dean.

**Completion of Prerequisite Courses** The sequences of required courses leading to various engineering degrees are carefully arranged to ensure that a student who enters any course may be expected to receive maximum benefit from the course. A student who failed a course may not normally enroll for any course that lists the failed course as a prerequisite before satisfactorily completing that course. Under unusual circumstances, exceptions may be made. Exceptions require written permission from the instructor of the failed course, all instructors of the subsequent course, and approval by the dean.

**Repeating Courses** A student who has received D grades in fundamental courses may be required to repeat those courses as his or her academic advisor or departmental

faculty may direct. A course in the School of Engineering and Applied Science passed with a grade of D may be repeated once. Courses passed with higher grades are not normally open to a student's repeated registration. Both grades for a repeated course are used in the computation for the grade point average.

**Graduate Courses** Undergraduates may be granted permission to take 600-level series courses in the School of Engineering and Applied Science. Qualifications include fourth-year standing and a cumulative grade point average of at least 3.2. 500-level courses are open to all fourth-year undergraduates.

**Required Courses** Courses specified in each degree curriculum are required, and changes or substitution are not ordinarily permitted. Any student who either drops or fails a required course must register anew for that specific course (or for its successor in case the original is no longer offered) and repeat the content in its entirety.

**General Education Program** Each undergraduate student must complete a program of studies in the humanities or social sciences that reflects a rationale or fulfills an objective. This program, equivalent to at least one half year of study, is fulfilled in part by taking courses offered through the Division of Technology, Culture, and Communication and in part through HSS electives selected from a list of approved humanities and social science courses.

**Elective Courses** The curricula include elective courses designed either as "general education elective," "technical elective," or "unrestricted elective."

1. HSS electives are selected from an approved list (available in A122 Thornton Hall) of humanities and social science offerings of the College of Arts and Sciences or other schools of the University, or from elective offerings of the Division of Technology, Culture, and Communication in the School of Engineering and Applied Science. Communication courses in the student's native or first language, regardless of their level, may not be used to satisfy this requirement.
2. Technical electives are chosen from engineering or applied science, science, or mathematics courses not normally required in the student's curriculum.
3. Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131, and courses that substantially duplicate any others offered for the degree, including PHYS 201, PHYS 202, CS 110, CS 120, or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should obtain the approval of their advisor and the dean's office, Thornton Hall, Room A122. APMA 109 counts as a three-

credit unrestricted elective for students who do not take APMA 111.

Students are expected to consult with their advisor to arrive at an acceptable overall program of electives. All electives should be chosen to meet an objective rather than at random. This program, signed by the department head or advisor, must be filed in the dean's office.

**Examinations** Written examinations are held at the end of each semester. Re-examinations are permitted only as provided in the following paragraph, and failure in any course requires reregistration and attendance in classes to establish eligibility for the next regular examination.

**Special Examinations** A candidate for a degree who is otherwise eligible but who has failed one course during the semester prior to graduation, may request permission to take a special examination to qualify for a passing grade in that course. Such permission may be granted only under justifiable circumstances, which includes the inability of the student to repeat the course. Permission is not granted if the student has failed the course twice. Application for special examination is submitted to the dean's office.

**Absence From Examinations** Unexcused absence from an examination incurs an automatic failure in the course with a grade of F. Absence from a final examination for any course offered in the School of Engineering and Applied Science may be excused only by the dean, and then only when accompanied by evidence of arrangement with the instructor for a deferred examination, to be taken within ten days after the regular examination. An emergency that justifies extension of this period will be considered only when supported by satisfactory documentation submitted immediately after the period of emergency. After the ten day period, or its extension if granted by the dean, the temporary grade of IN (incomplete) will officially become a grade of F unless the deferred examination has been completed. Absences are excused only for sickness on the day of the examination or for other providential cause acceptable to the dean. An excused absence may be absolved by taking a special examination at a time mutually satisfactory to the instructor and the student concerned. Special examinations are not granted for reasons other than those stated above.

### Degree Requirements

To qualify for a baccalaureate degree, a student must have received credit for all required and elective courses included in their program. In addition, the student must have maintained a cumulative grade point average of at least 2.0. Students must complete degree applications in September of their final year.

Regular programs leading to the various degrees are detailed under the departmental listings. The student should become familiar with the requirements of his or her chosen area of study. Students are expected to declare a major area of study at the end of the second semester but may change majors at a later date.

### Course Enrollment

Except for students in extended programs or for special arrangements approved by the dean, each student in the School of Engineering and Applied Science must enroll for all courses required by the curriculum of the department in which he or she is enrolled. Substitutions of courses completed elsewhere by students entering with advanced standing must be approved by the dean (in consultation with the departmental faculty concerned when necessary).

Students making normal progress toward their degree may graduate under the curriculum in force at the time they entered the school. However, because curricula change to keep pace with evolving technologies and new disciplines, students may be required to substitute courses that the faculty designate as equivalent.

Each student is responsible for the selection of his or her own program, the fulfillment of prerequisites, and the scheduling of all courses required by his or her curriculum. The dean and faculty will assist, but the duty of enrolling in and completing the full degree requirements rests primarily with the student.

### Accuracy of Students' Records

It is the student's responsibility to check the accuracy of his or her enrollment records each semester and to call any error to the attention of the instructor and assistant dean for undergraduate programs. After one semester has lapsed, the student's record is considered permanent.

### Residence Requirements

A recipient of a degree in engineering or applied science must have been in residence for two academic years in this University, and registered in the School of Engineering and Applied Science during the semester in which he or she receives a degree.

### ROTC Programs

The regular curricula can be supplemented to include Air, Military, or Naval Science courses. Depending on the ROTC branch and degree program, such a curriculum may take more than eight semesters to complete.

### Minors

The School of Engineering and Applied Science offers minors in aerospace engineering; applied mathematics; biomedical engineering; chemical engineering; applied mathematics;

civil engineering; computer science; electrical engineering; environmental engineering; materials science and engineering; mechanical engineering; structural engineering; systems engineering; transportation engineering; the history of science and technology; technology management and policy; and technology and the environment. Minors in these areas, or in areas offered by other academic units of the University, are not required for any of the SEAS degree programs.

### Curricula

The individual degree program curricula shown in this section went into effect for the entering class in the fall of 1999. As a result, certain courses may not be listed in the course description section. For inquiries concerning new courses, contact the Office of the Assistant Dean for Undergraduate Programs, School of Engineering and Applied Science, P.O. Box 400233, Charlottesville, Virginia 22904-4233. Additional information may also be available on the school's Web site at <http://www.seas.virginia.edu>.

The degree of Bachelor of Science is granted with the following majors:

- Aerospace Engineering
- Applied Mathematics
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Computer Science
- Electrical Engineering
- Engineering Science
- Mechanical Engineering
- Systems Engineering

The curricula leading to these degrees are arranged to prepare a graduate to enter directly into employment or to continue graduate studies in either scientific or engineering fields. The baccalaureate degrees include required and elective courses in technical subjects and applied mathematics; required and elective courses in the physical sciences; and elective mathematics, humanities, and social science courses. The aim of these curricula is to provide the student with a strong foundation in methods of engineering analysis, design, and synthesis, and to ensure a firm grasp of fundamental principles in science, mathematics, and the humanities.

All the curricula are accredited by the Southern Association of Colleges and Schools, and the professional engineering programs in aerospace, chemical, civil, computer, electrical, mechanical, and systems engineering are accredited by the Accreditation Board for Engineering and Technology (ABET), the accepted national agency for accrediting curricula in engineering.

The curricula that follow have been developed on the principle that instruction in engineering and applied science should prepare the graduate for professional practice as it has currently evolved and provide a firm

foundation in the physical sciences and mathematics that will encourage an imaginative and flexible approach to the problems of engineering and applied science of the future. Included in the student's first four semesters' work are elective courses in the humanities taught by the College of Arts and Sciences and a required Technology, Culture, and Communication (TCC) course in the School of Engineering and Applied Science. The elective College courses broaden the students' interests in fields outside of their technical program, and thus prepare them for a balanced and culturally rich life in the community. The School of Engineering and Applied Science TCC courses aim to encourage effective oral and written communication in both technical and non-technical pursuits, and to develop an appreciation for the interactions of technology and society students will encounter in both their professional lives and as responsible citizens.

The curriculum of the school does not require premature specialization. A nondepartmentalized core program covering most of the first two years is administered jointly by all departments. Most curricula have some requirements in the second-year program, and students should consult with their advisors and exercise judicious selection of electives to avail themselves of two or more options among major fields until the beginning of the third year.

### Aerospace Engineering

Aerospace engineering is concerned with the science and technology underlying the behavior and design of vehicles and systems that operate within the atmosphere and in space. It requires knowledge of a wide range of subject areas, including the basic sciences, mathematics, and engineering sciences as well as specialized studies in aerodynamics, propulsion systems, structures, materials, flight dynamics, astronautics, planetary atmospheres, and computational methods. This broad background qualifies the graduating engineer not only to handle problems that are special to the aerospace field, but also to meet challenges of an interdisciplinary nature facing society, such as those involving the environment, transportation, and energy resources.

With the changing climate in industry and educational units, increasing pressure is being placed on academic institutions to prepare students properly for the future workplace. Students need different experiences than they did ten years ago in order to be competitive in the changing industrial atmosphere. Rapidly expanding, global industries no longer have the resources for extensive "on the job" training. As indicated by discussions with recruiters and industry leaders, graduating students are now expected to have some practical and/or unique experience that they will be able to apply in an industry in the near term. These

experiences may come from either laboratory work at the University or from a co-operative education (co-op) program.

The School of Engineering and Applied Science and the Department of Mechanical and Aerospace Engineering implemented a co-op program in 1996 that is currently placing students with 40 industries.

This program builds self confidence, helps define career goals, assists with course selection, provides senior thesis material through industrial projects, eases transition to the industrial world, enhances marketability when seeking future employment, and provides income (wages are typically two-thirds of the salaries earned by B.S.M.E. or B.S.A.E.). It takes four and one-half years to complete the co-op program, including one extended stay (summer plus semester) in industry, with one or two more summers possible. Requirements include third year academic standing and a grade point average of at least 2.5. Participation is optional and non-credit; details can be obtained from the school or department.

**Minor** A minor in aerospace engineering is comprised of five courses and requires MAE 201. The other four courses must be chosen from MAE 210, MAE 231, MAE 232, MAE 263, MAE 264, MAE 310, MAE 312, MAE 314, MAE 321, MAE 322, MAE 331, MAE 342, MAE 352, MAE 363, MAE 364, MAE 373, MAE 381, MAE 382, MAE 412, MAE 413, MAE 454, MAE 465, MAE 466, MAE 473, MAE 493, MAE 494, MAE 497 and MAE 498.

### **Aerospace Engineering Curriculum (128 credits)**

#### **First Semester**

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers .....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

#### **Second Semester**

APMA 212	Multivariate Calculus .....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science.....	3
	Science elective I <sup>(1)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### **Third Semester**

MAE 209	Applied Probability and Statistics .....	3
PHYS 241E	General Physics II .....	3
PHYS 241L	General Physics Lab I.....	1
MAE 201	Intro to Aeroengineering.....	3
MAE 231	Statics and Strength of Materials.....	4
	HSS elective <sup>(2)</sup> .....	3
		17

#### **Fourth Semester**

APMA 213	Ordinary Differential Eq.....	4
MAE 210	Thermodynamics .....	3
MAE 232	Dynamics.....	3
MAE 202	Applications of Electronics...	3
TCC ____	TCC 2xx/3xx elective .....	3
		16

#### **Fifth Semester**

APMA 314	Vector Calculus and Partial Differential Eq.....	3
MAE 321	Fluid Mechanics .....	4
MAE 381	Experimental Methods Lab..	2
MAE 331	Aerospace Structures .....	3
MAE 352	Engineering Materials .....	3
		15

#### **Sixth Semester**

MAE 342	Computational Methods in Aerospace Engineering .....	3
MAE 322	Adv. Fluid Mechanics.....	3
MAE 331	Aero Structures .....	3
MAE 382	Aerodynamics Lab .....	3
	Unrestricted elective <sup>(3)</sup> .....	3
		15

#### **Seventh Semester**

TCC 401	Western Technology and Culture .....	3
MAE 373	Flight Vehicle Dynamics .....	3
MAE 465	Aerospace Design I.....	3
	Technical elective .....	3
	Unrestricted elective <sup>(3)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
MAE 412	Air Breathing Propulsion.....	3
		21

#### **Eighth Semester**

TCC 402	The Engineer in Society.....	3
MAE 466	Aerospace Design II .....	3
	Technical elective .....	3
	Technical elective .....	3
	Unrestricted elective <sup>(3)</sup> .....	3
		15

(1) Chosen from: BIOL 201, 202; CHEM 152; PHYS 252; and MSE 209.

(2) Chosen from the approved list available in A122 Thornton Hall.

(3) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.

### **Applied Mathematics**

This program, which offers a Bachelor of Science degree in Applied Mathematics, seeks to attract those who are interested in using mathematics to solve problems that occur in areas other than mathematics itself. A typical

student in this program takes eleven courses in mathematics (seven courses at the third- and fourth-year level) and concentrations in an area in which mathematics has been found to be useful, such as engineering, economics, physics, biology, or computer science.

The concentration consists of at least four 3-credit courses from University offerings in a single field. Approval for this concentration must be obtained from an advisor by the beginning of the third year. Technical electives may be chosen from any 300- or 400-level science or technical courses in the University. Subject to advisor approval, some 200-level courses in biology or chemistry may be chosen.

The degree program is quite flexible. Each student must complete the standard two years required of all students in the School of Engineering and Applied Science. In the last two years, the student is required to follow broad guidelines, but may tailor a program to obtain greater depth in one area or to explore the fundamentals of several areas.

**Minor** A minor in Applied Mathematics consists of five courses at the 300 level or above. These courses must include at least two from APMA 308, 310, and 314. Courses may be selected from APMA offerings as well as offerings in MATH or STAT in the College which are not substantial duplicates of SEAS courses taken by the student.

### **Applied Mathematics Curriculum (128 Credits)**

#### **First Semester**

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers .....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

#### **Second Semester**

APMA 212	Multivariate Calculus.....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science.....	3
	Science elective I <sup>(5)</sup> .....	3
	HSS elective <sup>(4)</sup> .....	3
		17

#### **Third Semester**

APMA 213	Ordinary Differential Eq.....	4
PHYS 241E	General Physics II.....	3
PHYS 241L	General Physics Lab I.....	1
	Engr. science elective <sup>(1)</sup> .....	3
	Engr. science elective <sup>(1)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		17

#### **Fourth Semester**

APMA 314	Vector Calculus and Partial Differential Eq.....	3
	Science elective II <sup>(2)</sup> .....	4
	Engr. Science elective <sup>(1)</sup> .....	3

	Engr. Science elective <sup>(1)</sup> .....	3
CS 201	Software Devel. Methods.....	3
		16

### Fifth Semester

APMA 310	Probability.....	3
APMA 308	Linear Algebra.....	3
	Minor/Tech. elective.....	3
	Minor/Tech. elective.....	3
	HSS elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		18

### Sixth Semester

MATH 334	Complex Variables.....	3
	APMA Elective <sup>(3)</sup> .....	3
	Concentration/Tech. elective.....	3
	Concentration/Tech. elective.....	3
TCC ____	TCC 2xx/3xx elective.....	3
		15

### Seventh Semester

TCC 401	Western Technology and Culture.....	3
APMA 507/		
MATH 430	Numerical Methods.....	3
	APMA Elective <sup>(3)</sup> .....	3
	Concentration/Tech. elective.....	3
	HSS elective <sup>(4)</sup> .....	3
		15

### Eighth Semester

TCC 402	The Engineer in Society.....	3
	APMA elective <sup>(3)</sup> .....	3
	APMA elective <sup>(3)</sup> .....	3
	Concentration/Tech. elective.....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		15

(1) Chosen from: APMA 202; CE 206, 207; CHE 202; CS 202, 230; EE 203, 230; MAE 202, 210, 231, 232; and MSE 209. One engineering science elective may be replaced by a science or technical elective.

(2) Chosen from: BIOL 201/203, 202/204; CHEM 212/212L, 152/152L; EVSC 280/280L; PHYS 252/252L. Science elective II must include a lab.

(3) Chosen from approved 300- or 400-level courses in APMA, MATH, or STAT.

(4) Chosen from the approved list available in A122 Thornton Hall.

(5) Chosen from: BIOL 201, 202; CHEM 152; MSE 209; and PHYS 252.

(6) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a

three-credit unrestricted elective for students who do not take APMA 111.

### Biomedical Engineering

Engineers and physicians share the view that science best serves humankind through its applications. In both professions, heightened understanding is producing a flood of new applications in the form of devices, materials, and techniques. The vigorous hybrid field of biomedical engineering has sprung from such shared outlooks and growing capabilities. Focusing on technology for problems of living systems, it makes synergistic use of the physical, mathematical, engineering, and biological sciences. The Department of Biomedical Engineering offers graduate degrees at the masters and doctoral levels, and an undergraduate minor that can be taken in conjunction with any of the majors within the School of Engineering and Applied Science.

A biomedical engineering track in the Engineering Science Program offers undergraduates the opportunity to design a course of study with a strong biomedical component. In addition to taking biomedical engineering courses, students who select this track are expected to work on a senior thesis project under the supervision of a BME faculty member. This undergraduate biomedical engineering track prepares students to pursue advanced graduate degrees in biomedical engineering or to prepare for medical school, but with a strong interest in biomedical applications of engineering and technology.

Judicious selection of biomedical engineering electives in the fourth year and a senior thesis topic that can continue onto a master of science thesis may allow graduation with the bachelor of science in four years, and the master of science or master of engineering in one additional year. Students interested in this option are strongly urged to plan early in their third year and to thoroughly discuss this plan with appropriate faculty in biomedical engineering.

Active research areas in the department include genetic engineering targeting vascular disease; vascular remodeling; cellular mechanisms of wound healing; biomechanics; bioelectricity; biotransport, emphasizing cardiovascular, respiratory, orthopaedic, and neurological systems; and technology in medicine, particularly ultrasound, X-ray, and MR imaging. Interdepartmental research collaboration links the Department of Biomedical Engineering with most other engineering departments and many clinical and basic science departments in the School of Medicine.

Preferred preparation for graduate study in the Department of Biomedical Engineering is a degree in biomedical, chemical, electrical, or mechanical engineering. Electives in life sciences should be taken to the extent possible, at least through cell biology (BIOM 304). The goal in course selection should be a

solid foundation in math and science within a traditional engineering field. Additional relevant electives include partial differential equations, linear algebra, statistics, solid or fluid mechanics, and signals and systems courses in electrical engineering.

**Minor** The 18-credit minor in biomedical engineering consists of BIOM 301 and 304, and MSE 512, plus 3 approved electives that may include CHE 447 and BIOM 411, 422, 441, and 484.

### Chemical Engineering

Chemical engineering applies physical, chemical, and engineering principles to the processing of such varied products as fuels, drugs, foods, plastics, metals, and basic chemicals. Undergraduate science preparation for this field is therefore especially broad and draws on chemistry, mathematics, physics, and in some cases, biology. The graduates of a chemical engineering program are well prepared for industrial practice as well as for graduate work in chemical engineering; biochemical or biomedical engineering; chemistry; environmental or energy studies; materials science; medicine; business administration; and law.

Many chemical engineers serve in the traditional chemical process industries of petroleum, chemicals, paper, pharmaceuticals, and plastics. Some develop new products or processes through research, while others carry out the pilot studies and design work to bring innovations from the laboratory into manufacturing operations. Many are engaged in the operation and management of process plants. Others are in marketing, developing new applications for, or solving problems arising from, the use of these products. Often a chemical engineer moves from one of these functions to the next as an idea develops into a full-scale production facility. Chemical engineers have long aided in energy and materials production from oil, gas, and coal. They are involved in the research, development, and production of energy from alternative energy resources. Similarly, their chemical expertise and broad knowledge of processes are valuable in the identification and control of environmental problems, in health care and pharmaceuticals, and in areas such as electronic materials production. A chemical engineer's career path is varied and rewarding, allowing individual talents to grow and be fully utilized.

The chemical engineering curriculum progresses from basic sciences and mathematics (with an emphasis on chemistry), through the engineering sciences, to applications in chemical process analysis, and culminates in a capstone design project. Computer methods, laboratory techniques, open-ended problem solving, team approaches, and effective written and oral communication are emphasized throughout the program of study. Elective courses permit emphasis

on various interest areas, while studies in the humanities and liberal arts can help to prepare the student to address the ethical, environmental, cultural, and economic impacts of technological activities.

### First-Year And Second-Year Program

Chemical engineering students take a two-semester sequence of general chemistry with the standard first-year program. Because of individual long term goals and the various options available for students in the chemical engineering program, early consultation with an advisor from the department is strongly recommended for program planning. For example, a student planning on medical school would schedule a full year of organic chemistry as well as biology courses.

**Minor** A minor in chemical engineering consists of CHE 215, 316, 318, 321, and 322.

### Chemical Engineering Curriculum (128 Credits)

#### First Semester

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers .....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

#### Second Semester

APMA 212	Multivariate Calculus .....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science.....	3
	Science elective I <sup>(1)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### Third Semester

APMA 213	Ordinary Differential Eq.....	4
PHYS 241E	General Physics II .....	3
PHYS 241L	General Physics Lab I.....	1
CHE 215	Material and Energy Balances.....	3
	ENGR elective <sup>(3)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### Fourth Semester

APMA 314	Vector Calculus and Partial Differential Eq. ....	3
CHEM 212	Intro to Organic Chem. ....	3
CHEM 212L	Organic Chem. Lab.....	1
CHE 202	Thermodynamics <sup>(4)</sup> .....	3
CHE 216	Modeling and Simulation in Chemical Engineering .....	3
TCC ____	TCC 2xx/3xx elective .....	3
		16

#### Fifth Semester

CHE 316	Chemical Thermodynamics..	3
CHE 321	Transport Processes I.....	4
CHEM 361	Physical Chemistry.....	3
CHEM 371	Intermediate Techniques in Chemical Experimentation..	3

Unrestricted elective<sup>(5)</sup> .....

3  
16

#### Sixth Semester

CHE 318	Chem. Reaction Engineering .....	3
CHE 322	Transport Processes II.....	4
CHE 398	Chem. Engineering Lab I.....	3
	Technical elective <sup>(6)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		16

#### Seventh Semester

TCC 401	Western Technology and Culture .....	3
CHE 438	Process Modeling, Dynamics, and Control.....	3
CHE 491	Chem. Engr. Lab II.....	3
	CHEM/SCI elective <sup>(7)</sup> .....	4
	Unrestricted elective <sup>(5)</sup> .....	3
		16

#### Eighth Semester

TCC 402	The Engineer in Society.....	3
CHE 476	Chem. Engineering Design...CHE elective <sup>(8)</sup> .....	3
	Technical elective <sup>(6)</sup> .....	3
	Unrestricted elective <sup>(5)</sup> .....	3
		15

- (1) CHEM 152/152L is strongly recommended as science elective I. If another course is selected from BIOL 201, 202; MSE 209; or PHYS 252, then CHEM 152/152L (needed for CHE majors) will satisfy the CHEM/SCI elective. See note 7.
- (2) Chosen from the approved list available in A122 Thornton Hall or from the department office.
- (3) Chosen from engineering science courses, such as CE 206; CS 230; ECE 203, 230; MAE 202, 231; and MSE 209. (MSE 209 is recommended.)
- (4) MAE 210 will also satisfy this course requirement.
- (5) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.
- (6) Any upper level (200 or above) science, math, or engineering courses. Courses must be approved by your advisor.
- (7) Chosen from a list of chemistry or natural science-related electives that is available in the department office. If CHEM 152/152L is used as science elective I, then this elective is a 3-credit course.

- (8) Chosen from a list of chemical engineering electives available in the department office.

### Civil Engineering

Civil engineering is the application of science and technology to the planning, design, analysis, construction, operation, and maintenance of the physical facilities required by society. It is the broadest of all engineering professions, encompassing activities from aerospace to urban planning. Civil engineers are the fabricators of modern society and the protectors of our environment. They deal with people and their management, materials and their use, designs and their application, and the problems of interweaving these factors to serve society. Typical civil engineering projects include environmental facilities, such as systems for water quality control, toxic and hazardous waste control and storm water networks; structures, such as high-rise buildings, bridges, off-shore platforms, shuttle launch pads, and dams; and transportation facilities, such as Intelligent Transportation Systems, airports, highways, and railways. Civil engineering has a long history and a bright future serving the basic needs of society.

Civil engineering graduates with a BS degree may opt for employment with high technology consulting firms; local, state, or federal government; contractors or construction firms; public utilities; or industrial corporations. Another option is graduate school, where students pursue an area of specialty within civil engineering. Such studies open up more advanced employment opportunities in government, consulting, construction, or industry, and introduce new choices, including research and teaching. A civil engineering degree also provides a good background for professional training in law, business administration, or medicine.

**Minor** The 15-credit minor in civil engineering may be obtained in one of four areas: environmental engineering (choose five): CE 205, 315, 336, 420, 430, or 440; structural engineering: CE 316, 319, 323, 326, and 401; transportation engineering: CE 344, 444, 445, 446 and APMA 312; and general civil engineering, which includes any five courses from the above lists.

### Civil Engineering Curriculum (128 Credits)

#### First Semester

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers.....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

**Second Semester**

APMA 212	Multivariate Calculus .....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science ..	3
	Science elective I <sup>(1)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

**Third Semester**

APMA 308	Linear Algebra.....	3
PHYS 241E	General Physics II .....	3
PHYS 241L	General Physics Lab I.....	1
	CE elective <sup>(5)</sup> .....	3
CE 206	Solid Mechanics .....	4
	HSS elective <sup>(2)</sup> .....	3
		17

**Fourth Semester**

APMA 213	Ordinary Differential Eq.....	4
CE 207	Dynamics.....	3
CE 209	CE Probability and Statistics.....	3
CE 315/365	Fluid Mechanics/Lab .....	4
TCC ____	TCC 2xx/3xx elective .....	3
		17

**Fifth Semester**

CE 319	Structural Mechanics.....	3
CE 323/363	Properties and Behavior of Materials/Lab.....	4
	Elective <sup>(6)</sup> .....	3
	Unrestricted elective <sup>(7)</sup> .....	3
CE 336	Water Resources .....	3
		16

**Sixth Semester**

CE 316/316L	Introduction to Geotechnical Engr./Lab.....	4
CE 326	Design Concrete Structures..	3
CE 344	Transportation Engr. I .....	3
	HSS elective <sup>(2)</sup> .....	3
CE ____	CE required elective <sup>(4)</sup> .....	3
		16

**Seventh Semester**

TCC 401	Western Technology and Culture.....	3
CE 490	CE Design and Practice .....	3
CE ____	CE required elective <sup>(4)</sup> .....	3
CE ____	CE required elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(7)</sup> .....	3
		15

**Eighth Semester**

TCC 402	The Engineer in Society .....	3
CE ____	CE required elective <sup>(4)</sup> .....	3
CE ____	CE required elective <sup>(4)</sup> .....	3
	Elective <sup>(3)</sup> .....	3
	Unrestricted elective <sup>(7)</sup> .....	3
		15

128 credits - minimum required for graduation.

(1) Chosen from: BIOL 201, 202; CHEM 152; MSE 209; and PHYS 252.

(2) Chosen from the approved list available in A122 Thornton Hall.

(3) All 300- and 400-level SEAS courses (with the exception of TCC courses, ENGR 488, TMP 352, TMP 355) and selected environmental science courses.

Only one of MAE 400 (Financial Aspects of Eng.) or CE 341, but not both, may be used to satisfy this requirement and requirements (4) and (6).

(4) CE Dept. requirement. Any 300- or 400-level Civil Engineering course. Only one of MAE 400 (Financial Aspects of Eng.) or CE 341, but not both, may be used to satisfy a CE Dept. requirement or requirements (3) and (6).

(5) Chosen from: CE 205, MAE 210, or EE 203.

(6) Chosen from: BIOL 201, 202; CHEM 152, 212; EVSC 280; MSE 209; PHYS 252; and all 200-, 300- and 400-level SEAS courses (with the exception of TCC courses, ENGR 488, TMP 352, TMP 355) and selected environmental sciences courses. Only one of MAE 400 (Financial Aspects of Eng.) or CE 341, but not both, may be used to satisfy this requirement and requirements (3) and (4).

(7) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.

**Computer Engineering (CPE)**

Computer Engineering is an exciting field that spans topics in both electrical engineering and computer science. Students learn and practice the design and analysis of computer systems, including both hardware and software aspects and their integration. Careers in computer engineering are as wide and varied as computer systems themselves, which range from embedded computer systems found in consumer products or medical devices, to control systems for automobiles, aircraft, and trains, to more wide-ranging applications in telecommunications, financial transactions, and information systems.

According to the Bureau of Labor Statistics, computer engineering is one of the fastest growing occupations, with a projected need to fill 235,000 jobs between 1996 and 2006.

The primary objective of the undergraduate Computer Engineering Program is to provide a solid education in the fundamentals of both computer science and electrical engineering so that graduates are prepared to enter into practice or to continue their education as graduate students. The program's goals are to help students achieve the technical qualifications necessary to solve the engineering problems of tomorrow; to facilitate the development of problem-solving, group,

and communication skills; to instill an understanding of the effects that technology can have on humanity; and, finally, to inspire students to strive for continuous self-renewal throughout their careers.

Faculties from the Electrical Engineering and Computer Science departments jointly administer the computer engineering undergraduate degree program at the University of Virginia.

In order to major in computer engineering, a formal application must be submitted and approved by the Computer Engineering Curriculum Committee. An application form and a description of acceptance policies can be found at [www.cpe.virginia.edu](http://www.cpe.virginia.edu).

Computer engineering majors must maintain a C average or better in their computer science and electrical engineering courses.

**Computer Engineering Curriculum (128 credits)****First Semester**

APMA 111	Single Variable Calculus. ....	4
CHEM 151	Chem for Engineers .....	3
CHEM 151L	Chem for Engineers Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Lang Comm & Tech Soc.....	3
		15

**Second Semester**

APMA 212	Multivariate Calculus. ....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to CS .....	3
	Science Elective I <sup>(2)</sup> .....	3
	HSS Elective <sup>(1)</sup> .....	3
		17

**Third Semester**

APMA 213	Ordinary differential Equations. ....	4
CS 201	Software Development Meth3	
CS 202	Discrete Mathematics I.....	3
ECE 203	Intro Circuit Analysis.....	3
	HSS Elective <sup>(1)</sup> .....	3
		16

**Fourth Semester**

CS 216	Program and Data Representation .....	3
ECE 204	Electronics I.....	4
CS/ECE 230	Digital Logic Design.....	3
	CS/ECE Elective <sup>(4)</sup> <sup>(6)</sup> .....	3
	TCC Elective.....	3
		16

**Fifth Semester**

APMA 310	Probability .....	3
ECE 323	Signals and Systems .....	3
CS/ECE 333	Computer Architecture .....	3
PHYS 241E	Physics II .....	3
PHYS 241L	Physics Lab .....	1
	Unrestricted elective <sup>(5)</sup> .....	3
		16

**Sixth Semester**

CS 340	Advanced Software Development Techniques .....	3
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CS 414	Operating Systems.....	3
	CS/ECE Elective <sup>(4)</sup> <sup>(6)</sup> .....	3
	Technical Elective <sup>(3)</sup> .....	3
	HSS elective <sup>(1)</sup> .....	3
		15

### Seventh Semester

TCC 401	Western Technology and Culture.....	3
CS/ECE 457	Computer Networks.....	3
ECE 435	ECE Computer Design .....	4½
	CS/ECE elective <sup>(4)</sup> <sup>(6)</sup> .....	3
	Unrestricted elective <sup>(5)</sup> .....	3
		16½

### Eighth Semester

TCC 402	The Engineer in Society .....	3
ECE 436	Advanced Digital Design.....	4½
	CS/ECE elective <sup>(4)</sup> <sup>(6)</sup> .....	3
	Technical Elective <sup>(3)</sup> .....	3
	Unrestricted elective <sup>(5)</sup> .....	3
		16½

(1) Chosen from the approved list available in A122 Thornton Hall.

(2) Chosen from: among BIOL 201, 202; CHEM 152; MSE 209; and PHYS 252.

(3) A technical elective is a course in engineering, mathematics, or science at the 200 level or above.

(4) Students interested in selected advanced CS electives should take CS 302. Students interested in selected advanced ECE electives should delay this elective until the sixth semester and take an engineering elective instead.

(5) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111/ECE.

(6) Chosen from CS/ECE course at the 300 level or higher. Two CS/ECE electives must be 400 level or above.

### Computer Science

Through the development of sophisticated computer systems, processors, and embedded applications, computer scientists have the opportunity to change society in ways unimagined several years ago. The degree goal is the education and training of students who can lead the current information technology revolution. To this end, the computer science program orients students toward the pragmatic "engineering" aspects of computer science. Good engineering is rooted in solid mathematics and science, and a grounding in these fundamentals is essential. Provided in the context of the practice of

computing, this early grounding forms the basis for an education that outstandingly prepares students for a computing career.

As a discipline, computer science has seen many dramatic changes in its brief history. Traditional programming instruction emphasizes writing short programs from scratch in a dead language. This emphasis contrasts with the skills needed by contemporary computing professionals. With funding from the National Science Foundation, the Department of Computer Science has designed, developed, and is currently disseminating a new curriculum focused on the *practice* of computing, yet grounded in the mathematical and scientific fundamentals of computer science. The curriculum is structured around the introduction of modern software development techniques in the very beginning courses and is supported by a coordinated set of "closed laboratories."

In order to provide an environment appropriate to our courses, the department has established several laboratories with more than 60 workstations. These machines have high-resolution graphics and are connected to large file handlers, as well as to the University network. The lab courses expose students to many commercial software tools and systems and are currently introducing modern software development techniques via object-oriented design and implementation in C++.

The Department of Computer Science co-offers, with the Department of Electrical Engineering, a degree in Computer Engineering.

In order to major or minor in computer science or computer engineering, a formal application must be submitted to, and approved by, the Department of Computer Science. An application form and a description of acceptance policies can be found at [www.cs.virginia.edu](http://www.cs.virginia.edu). Applications are considered at the end of the spring semester.

Computer science majors and minors are required to maintain a C average or better in their CS courses.

**Transfer** Students in the College of Arts and Sciences with an interest in obtaining a degree in computer science may transfer to the School of Engineering and Applied Science. Like other SEAS students, transfer students must formally apply to, and be approved by, the Department of Computer Science to take the Computer Science program of study. To minimize loss of credit upon transfer, College students must take a rigorous program in mathematics and the sciences. The School of Engineering and Applied Science expects a minimum of 63 credits in the first two years, instead of the 60-credit minimum that is customary in the College of Arts and Sciences. (The extra credits are often completed by transfer students through summer courses.) Detailed information on curriculum requirements

may be obtained from the Office of the Dean of the School of Engineering and Applied Science.

**Minor** The 18-credit computer science minor consists of CS 101, 201, 202, and 216. In addition, two other computer science courses from a prescribed list must be taken. Complete details can be found at the computer science Web site, [www.cs.virginia.edu](http://www.cs.virginia.edu).

### Computer Science Curriculum (126 ½ credits)

#### First Semester

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers.....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

#### Second Semester

APMA 212	Multivariate Calculus .....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science .....	3
	Science elective I <sup>(1)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### Third Semester

APMA 213	Ordinary Differential Eq.....	4
PHYS 241E	General Physics II.....	3
PHYS 241L	General Physics Lab I.....	1
CS 201	Software Devel. Methods.....	3
CS 202	Discrete Mathematics I.....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### Fourth Semester

CS 302	Discrete Mathematics II .....	3
CS 216	Program and Data Representation .....	3
CS/ECE 230	Digital Logic Design.....	3
	Technical elective <sup>(3)</sup> .....	3
TCC ____	TCC 2xx/3xx elective .....	3
		15

#### Fifth Semester

APMA 310	Probability .....	3
CS 332	Algorithms.....	3
CS/ECE 333	Computer Architecture .....	3
	Technical elective <sup>(3)</sup> .....	3
	Unrestricted elective <sup>(4)</sup> .....	3
		15

#### Sixth Semester

APMA 308	Linear Algebra .....	3
CS 340	Advanced Software Development Techniques .....	3
CS 390	CS Seminar I.....	1
CS 414	Operating Systems .....	3
	Technical elective <sup>(3)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		16

#### Seventh Semester

TCC 401	Western Technology and Culture .....	3
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ECE 435	Computer Organization and Design.....	4½
CS ____	CS elective.....	3
CS ____	CS elective.....	3
	Unrestricted elective <sup>(4)</sup> .....	3
		16½

### Eighth Semester

TCC 402	The Engineer in Society .....	3
CS ____	CS elective.....	3
CS ____	CS elective.....	3
	Technical elective <sup>(3)</sup> .....	3
	Unrestricted elective <sup>(4)</sup> .....	3
		15

(1) Chosen from: BIOL 201, 202; CHEM 152; MSE 209; and PHYS 252.

(2) Chosen from the approved list available in A122 Thornton Hall.

(3) Technical electives are courses whose major emphasis is mathematics, science, or engineering. Two courses must be selected from the same department. At most, one technical elective can be at the 200 level. The other electives must be at level 300 or above.

(4) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.

### Electrical and Computer Engineering

Electrical engineering is a rapidly expanding field, and includes such areas as communications, microelectronics, control systems, and computer system design. New and exciting areas are continually being developed, and more traditional areas are finding new applications. Because of the rapidly-changing nature of the field, this program is designed to provide a strong preparation in traditional electrical engineering, while providing maximum flexibility to accommodate student interests and current technological developments. The aim is to provide a firm foundation in the fundamentals of the discipline, combined with sufficient depth in a chosen area to prepare the student for diverse employment opportunities or for graduate study in electrical engineering or related fields.

Students can use the flexibility available in the elective program to focus their study on an area of particular interest within electrical engineering, including communication systems, digital system design, control

systems, applied electrophysics, and microelectronics. In addition, with careful planning, students can use technical electives for interdisciplinary studies; for example, computer science, biomedical engineering, or materials science, perhaps even earning a minor in a related field. Specific suggestions for study in several areas are available from the departmental office.

**Minor** The 19-credit minor consists of ECE 203, 204, and 230, as well as 3 electives (with at least one course at the 400 level or above). The electives are selected from a list of courses available in the electrical engineering office.

### Electrical and Computer Engineering Curriculum

#### First Semester

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers .....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering.....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

#### Second Semester

APMA 212	Multivariate Calculus .....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science.....	3
	Science elective I <sup>(2)</sup> .....	3
	HSS elective <sup>(1)</sup> .....	3
		17

#### Third Semester

APMA 213	Ordinary Differential Eq.....	4
PHYS 241E	General Physics II .....	3
PHYS 241L	General Physics Lab I.....	1
ECE 203	Intro Circuit Analysis.....	3
CS 201	Software Devel. Methods.....	3
	HSS elective <sup>(1)</sup> .....	3
		17

#### Fourth Semester

	Mathematics elective <sup>(3)</sup> .....	3
ECE 204	Electronics I.....	4
ECE 230	Digital Logic Design .....	3
	Technical elective <sup>(4)</sup> .....	3
TCC ____	TCC 2xx/3xx elective .....	3
		16

#### Fifth Semester

ECE 309	Electromagnetic Fields .....	3
ECE 323	Signals and Systems .....	3
ECE 3__	ECE elective.....	3
	Technical elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		15

#### Sixth Semester

APMA 310	Probability.....	3
ECE 333	Computer Architecture.....	3
ECE 3__	ECE elective.....	3
	Technical elective <sup>(4)</sup> .....	3
	HSS elective <sup>(1)</sup> .....	3
		15

### Seventh Semester

TCC 401	Western Technology and Culture.....	3
ECE ____	ECE elective <sup>(5)</sup> .....	3
ECE ____	ECE Lab elective <sup>(5)</sup> .....	1½
ECE ____	ECE elective <sup>(5)</sup> .....	3
	ECE/CS elective <sup>(7)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		16½

### Eighth Semester

TCC 402	The Engineer in Society .....	3
ECE ____	ECE elective <sup>(5)</sup> .....	3
ECE ____	ECE Lab elective <sup>(5)</sup> .....	1½
ECE ____	ECE elective <sup>(5)</sup> .....	3
	Technical elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		16½

(1) Chosen from the approved list available in A122 Thornton Hall.

(2) Chosen from: BIOL 201, 202; CHEM 152; MSE 209; and PHYS 252.

(3) Selected from courses in the Departments of Mathematics or Applied Mathematics at the 200 level or higher.

(4) A technical elective is defined as a course in engineering (may be ECE), mathematics, or science (intended for science majors) at the 200 level or above. Of the four technical electives, two must be at the 300 level or above. Any course appearing on the approved list of HSS electives may not be used as a technical elective.

(5) ECE 435 and 436 each count as one course and one lab if chosen as electives. At least two courses and one lab must fall within a single area of concentration, and at least one course must be taken in another area of concentration. The five areas of concentration are applied electrophysics, communications and signal processing, digital systems, controls, and microelectronics. A list of electives that fulfill the requirements of each concentration is included in the *Electrical Engineering Undergraduate Handbook*.

(6) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.

(7) If a CS course is chosen, it must be at the 200 level or higher.

### Engineering Science

Engineering Science is a flexible program, offering imaginative students in the School of Engineering and Applied Sciences the oppor-

tunity to design a course of studies that appeals to their special academic interests and prepares them for graduate school. This flexibility allows students to develop expertise in topical areas in the biological, environmental, and physical sciences. Students typically select engineering science to prepare for a career in materials science, engineering physics, biomedical engineering, medical research, or medicine, all of which have strong graduate programs at the University of Virginia. Alternatively, some students seek to obtain a broad engineering/science background as preparation for work in non-engineering fields, such as teaching.

Engineering science students, in collaboration with their advisors, define their own program of studies. The study plan for each student must show direction by including an approved minor in the School of Engineering and Applied Science. The equivalent of a minor in a science area is also strongly encouraged. The advanced project course in the fourth year, which supplements the senior thesis, also allows the student to complete an in-depth research project.

The Department of Materials Science and Engineering has developed a materials science and engineering (MSE) option in this program intended to prepare students for either graduate school in MSE or to obtain a position in the materials industry. The courses recommended for the MSE option are described later in this section. In addition, a pre-med option has been developed in conjunction with the office of the pre-professional advisor for undergraduate degree programs.

### Engineering Science Curriculum (127 credits)

#### First Semester

APMA 111	Single Variable Calculus .....	4
CHEM 151	Introductory Chemistry for Engineers .....	3
CHEM 151L	Intro Chemistry Lab.....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	3
		15

#### Second Semester

APMA 212	Multivariate Calculus .....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science....	3
	Science elective I <sup>(1)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### Third Semester

APMA 213	Ordinary Differential Eq.....	4
PHYS 241E	General Physics II .....	3
PHYS 241L	General Physics II Lab.....	1
	Engr Science elective <sup>(3)</sup> .....	3
	Engr Science elective <sup>(3)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		17

#### Fourth Semester

	Math elective I <sup>(4)</sup> .....	3
	Science elective II <sup>(5)</sup> .....	3
	Science elective II Lab <sup>(5)</sup> .....	1
	Engr Science elective <sup>(3)</sup> .....	3
	Technical elective 2xx <sup>(5)</sup> .....	3
TCC ____	TCC 2xx/3xx elective .....	3
		16

#### Fifth Semester

	Adv. Math/CS elective II <sup>(4)</sup> ...	3
	Adv. Natural Science elec. <sup>(6)</sup> ...	3
	Adv. Natural Science Lab elec. <sup>(6)</sup> .....	1
	Technical elective <sup>(7)</sup> .....	3
	Technical elective <sup>(7)</sup> .....	3
	HSS elective <sup>(2)</sup> .....	3
		16

#### Sixth Semester

	Adv. Math/ CS elective II <sup>(4)</sup> .....	3
	Adv. Natrl. Science elec. <sup>(6)</sup> ...	3
	Adv. Natural Science Lab elec. <sup>(6)</sup> .....	1
	Technical elective <sup>(7)</sup> .....	3
	Technical elective <sup>(7)</sup> .....	3
	Unrestricted elective <sup>(9)</sup> .....	3
		16

#### Seventh Semester

TCC 401	Western Technology and Culture .....	3
	Technical elective <sup>(7)</sup> .....	3
	Technical elective <sup>(7)</sup> .....	3
	Advanced Project <sup>(8)</sup> .....	3
	Unrestricted elective <sup>(9)</sup> .....	3
		15

#### Eighth Semester

TCC 402	The Engineer in Society.....	3
	Technical elective <sup>(7)</sup> .....	3
	Technical elective <sup>(7)</sup> .....	3
	Advanced Project <sup>(8)</sup> .....	3
	Unrestricted elective <sup>(9)</sup> .....	3
		15

- (1) Chosen from: BIOL 201, 202; CHEM 152; MSE 209; and PHYS 252.
- (2) Chosen from the approved list available in A122 Thornton Hall.
- (3) Chosen from: CE 206, 207; CHE 202; ECE 203; MAE 202, 210, 231, 232; and MSE 209.
- (4) Math elective I: APMA 314 or a 200-level (or higher) course in mathematics is recommended. Advanced math/CS elective II: Two advanced mathematics courses, 300-level or higher, in SEAS or CLAS, or one advanced-level mathematics and one 200-level or higher computer science course. Mathematical modeling courses in the various departments of SEAS may be used, as approved by the advisor.
- (5) Chosen from: ASTR 211, 212; BIOL 201, 202, 203, 204; CHEM 152, 152L, 210, 222, 241, 241L, 242, 242L, 252, 281, 281L, 282, 282L; EVSC 280, 280L; MSE 209; PHYS 252, 252L; and PSYC 221. The four-course sequence for science majors

(CHEM 181/181L, 182/182L, 281/281L, 282/282L) may be taken to replace CHEM 151/151L, two science electives, and the 2xx technical elective. The course sequence for science majors (PHYS 151, 152, 251, 252, and labs PHYS 221, 222) may replace PHYS 142E, 241E/241L, and two science electives.

- (6) Advanced sciences are 300-level or above courses in astronomy, biology, chemistry, environmental sciences, or physics. The course must have mathematics or science prerequisites. For students with minors in engineering other than the materials science minor, 300-level courses in materials science may be used. Two credits of advanced laboratory work should be included. The science elective and technical electives should be used to obtain the equivalent of a science minor. Only one minor can be listed on a transcript.
- (7) Advanced technical electives should be chosen from 300- to 400-level science, mathematics, or engineering courses for science and engineering majors (i.e., courses not open to non-science majors). At least two of the technical electives must be 400-level or higher SEAS courses. The technical electives must be chosen to include an approved minor in SEAS.
- (8) Students are expected to define a research project to be completed in the fourth year. The advanced project courses are graded research courses supplementing the student's thesis work.
- (9) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.

### Materials Science and Engineering

The Department of Materials Science and Engineering offers a selection of undergraduate courses with the objective of providing a fundamental background in the structure, properties, processing, and performance of materials. This background is essential to engineers or scientists in understanding the selection of materials for various applications. The department encourages students to consider the field of materials science and engineering, a challenging new field in engineering. A materials science and engineering option is available to the undergraduate student within the framework of the Engineer-

ing Science Program. The Department of Materials Science and Engineering offers graduate degrees at the master's and doctoral levels, and an undergraduate minor that can be taken in conjunction with any of the majors within the School of Engineering and Applied Science. In the Materials Science Option, the student may select from a range of basic materials courses. A broad background in materials science and engineering is available by selecting MSE 209 (Introduction to the Science and Engineering of Materials), which develops the terminology and scientific foundation necessary for understanding the behavior of metals, polymers, and ceramics. More advanced courses are available to provide the student with modern and classical aspects of corrosion, as well as specific structure-property relationships for various classes of materials, such as alloys and polymers. Several laboratory sections introduce the student to typical experimental techniques for characterizing materials and their properties. Qualified students may also take 600-level graduate courses in materials science and engineering with the approval of the instructor. A general materials course, MSE 201 (EVSC 201), emphasizing the relationship of materials technology to modern society, is offered each semester for students of all disciplines.

Research opportunities exist for undergraduate students interested in working with faculty on project areas identified in the Graduate Record.

**Minor** Six courses constitute a minor. Required courses are MSE 305, 310L, and either MSE 209 or MAE 352. Select three of the following: MSE 301, 304, 306, 524, 532, 567; ENGR 495. Students studying civil engineering, applied mechanics, mechanical and aerospace engineering, chemical engineering, and systems engineering should consider MSE 301, 306, 524, and 532. Students studying electrical engineering, computer science, and systems engineering should consider MSE 304, 524, 567; and ENGR 495. Although not required for the minor, the laboratories associated with courses MSE 301 and 306 are recommended.

### Mechanical Engineering

Mechanical engineering is the broadest of the engineering disciplines, providing opportunities for employment in industry, business, government, research, and education. The mechanical engineer is concerned with the development of machines and systems for diverse applications in our modern technological society. Talents and interests of a graduate M.E. include those required to plan, analyze, design, and improve components and systems. The practice of mechanical engineering is applied to manufacturing, energy conversion, transportation, construction, and environmental control. In the future, mechanical engineers must provide

leadership in developing new sources of power and new systems to accommodate societal demands.

The curriculum begins with the study of chemistry, physics, mathematics, computer science, and general engineering courses. As the students progress, they take advanced analysis, design, and laboratory courses related to mechanical and thermal systems. One-fourth of the program is devoted to the humanities and social sciences, which broaden the student's education and assist in developing communication and leadership skills.

Young engineers need relevant experiences to be competitive in the global economy. As indicated by discussions with recruiters and industry leaders, graduating students are now expected to have some practical and/or unique experience that they will be able to apply in an industry in the near term. These experiences may come from laboratory work, projects at the University, or a co-operative education (co-op) program.

The School of Engineering and Applied Science and the Department of Mechanical and Aerospace Engineering implemented a co-op program in 1996 that now offers co-op experiences with more than forty companies. Thus far, approximately 20 students have been placed.

Participation in this program builds self confidence, helps define career goals, assists with course selection, provides senior thesis topics through industrial projects, eases transition to the industrial world, enhances marketability, and provides income (salaries are typically two-thirds of those for B.S. level engineers). It takes four and one-half years to complete the program, including one extended stay (summer plus a semester) in industry, with one or two more summers possible. Requirements include third year academic standing and a grade point average of at least 2.5. Participation is optional and non-credit. Details can be obtained from the school or department.

**Minor** Five mechanical engineering courses (15 credits minimum), passed with a minimum grade of C, may be selected from a large list of third- and fourth-year courses. The program of study for the minor must have a theme, and must be submitted to the MAE undergraduate study committee. There are three options: general mechanical engineering; thermal fluid systems; or dynamics, control, and design. Possible minor sequences include general mechanical engineering: MAE 200, 321, 312, 314, and 362; or MAE 321, 312, 314, 352, and 362; thermal fluid systems: MAE 321, 312, 314, 463, and 464, or MAE 321, 322, 312, 314, 411, and 412; dynamics, controls, and design: MAE 200, 352, 362, 465, and 452, or MAE 200, 352, 362, 474, and 473.

### Mechanical Engineering Curriculum (128 credits)

#### First Semester

APMA 111	Single Variable Calculus	.....4
CHEM 151	Introductory Chemistry for Engineers	.....3
CHEM 151L	Intro Chemistry Lab	.....1
ENGR 162	Intro to Engineering	.....4
TCC 101	Language Communication & the Technological Society	.....3
		15

#### Second Semester

APMA 212	Multivariate Calculus	.....4
PHYS 142E	General Physics I	.....4
CS 101	Intro Computer Science	.....3
	Science elective I <sup>(1)</sup>	.....3
	HSS elective <sup>(2)</sup>	.....3
		17

#### Third Semester

MAE 209	Applied Probability and Statistics	.....3
PHYS 241E	General Physics II	.....3
PHYS 241L	General Physics Lab I	.....1
MAE 231	Statics and Strength of Materials	.....4
MAE 200	Intro to Mechanical Engr.	.....3
	HSS elective <sup>(2)</sup>	.....3
		17

#### Fourth Semester

APMA 213	Ordinary Differential Eq.	.....4
MAE 232	Dynamics	.....3
MAE 210	Thermodynamics	.....3
MAE 202	Applications of Electronics	.....3
TCC ____	TCC 2xx/3xx elective	.....3
		16

#### Fifth Semester

MAE 381	Experimental Methods Lab.	.....2
MAE 371	Mechanical Sys. Modeling	.....3
MAE 321	Fluid Mechanics	.....4
	Math/Science II elective <sup>(3)</sup>	.....3
	Unrestricted elective <sup>(5)(6)</sup>	.....3
		15

#### Sixth Semester

MAE 362	Machine Elements and Fatigue in Design	.....4
MAE 314	Heat & Mass Transfer	.....4
	Technical elective <sup>(4)</sup>	.....3
	Technical elective <sup>(4)(6)</sup>	.....3
	HSS elective <sup>(2)</sup>	.....3
		17

#### Seventh Semester

TCC 401	Western Technology and Culture	.....3
MAE 471	Mechatronics	.....4
MAE 461/463	Design I elective	.....3
	Technical elective <sup>(4)(6)</sup>	.....3
	Unrestricted elective <sup>(5)</sup>	.....3
		16

#### Eighth Semester

TCC 402	The Engineer in Society	.....3
MAE 462/464	Design II elective	.....3
	Technical elective <sup>(4)</sup>	.....3
	Technical elective <sup>(4)(6)</sup>	.....3

Unrestricted elective<sup>(5)(6)</sup>.....3  
15

- (1) Chosen from: BIOL 201, 202; CHEM 152; MSE 209; or PHYS 252.
- (2) Chosen from the approved list available in A122 Thornton Hall.
- (3) Suitable math/science electives are all courses satisfying science elective I, plus APMA 202 and all APMA and MATH courses at the 300 level or higher.
- (4) A student must satisfy three of the technical electives from among APMA 314; MAE 312, 322, 352, 400, 473, and 474.
- (5) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.
- (6) Indicates five courses that could be used to obtain a minor within SEAS. A minor can be obtained in the College of Arts and Sciences by appropriate use of HSS and unrestricted electives.

## Systems and Information Engineering

The department offers both undergraduate and graduate degrees in systems engineering. The principal objective of the undergraduate program is to prepare men and women to be leaders in technology and to pursue professional careers and advanced studies in systems engineering. This demands not only a thorough understanding of the engineering fundamentals of systems analysis, design, and control, but also education in information systems, economics, behavioral science, and decision-making.

At the heart of the systems engineering curriculum are the disciplines of design and modeling that define the core competencies of the professional systems engineer. The principles of large-scale design and modeling run through all courses in a curriculum that prepares students for one of three primary career paths: engineering management; information engineering; and operations and control systems engineering. Students select courses based on their choice of track. Mixing courses between tracks is permitted but should be discussed with an advisor.

The engineering management option prepares students for careers in strategic consulting, business analysis, financial engineering, and management (particularly operations management). Courses in this curriculum show how to model and analyze business problems and are supplemented with elec-

tives from commerce, economics, and the social sciences. This track provides excellent preparation for graduate work in business, law, the social sciences, and engineering and technology management.

The information engineering option prepares students for careers in information technology consulting, systems analysis, database administration, network operations and management, and systems integration. Currently, the U.S. has more jobs in this area than in any other technical field. The curriculum emphasizes the use of modeling to design, integrate, maintain, and operate information systems. Students in this track are also given excellent preparation for graduate degrees in information systems, systems engineering, business, and computer science.

The operations analysis and control systems engineering track prepares students for careers in technical services, such as control systems engineering, operations analysis, and research engineering in industrial and government organizations. The track emphasizes mathematical and engineering modeling of large-scale systems from a variety of applications, including communications, transportation, manufacturing, health care, and environmental engineering. Students are expected to develop the full range of problem-solving, decision-making, and design skills needed to participate successfully in these application areas. The track provides outstanding preparation for students interested in graduate degrees in systems engineering and other engineering disciplines, as well as medicine and the physical sciences.

Regardless of the track chosen, the interdisciplinary nature of systems engineering precludes a narrow educational experience. For this reason, this undergraduate curriculum is more flexible than many traditional engineering programs. In addition to required courses, nine credits each of humanities and social sciences, applications, and unrestricted electives; and 6 credits of technical electives; and a 3-credit elective from technology, culture, and communication (a total of 36 elective credits) are available to the student.

Appropriate humanities sequences include economics, psychology, political science, philosophy, religion, history, literature, fine arts, sociology, anthropology, and foreign languages. Applications sequences define the major track pursued by the student but also allow for a more narrow focus.

Example applications sequences include biomedical systems, communication systems, computer and information systems, control systems, economic systems, environmental and water-resource systems, management systems, manufacturing systems, mathematical systems, and transportation and land-use systems. An appropriate sequence of ROTC courses may be counted as an application area in military systems,

and students with special interests and abilities can design their own application sequences.

The undergraduate program culminates in a capstone design project spanning both the fall and spring semesters of the fourth year. Each project matches a small team of students with a client from the private or public sectors. Students work with the client, under the direction of an individual faculty member, toward the resolution of an actual, open-ended design problem.

The undergraduate program, which leads to the Bachelor of Science in Systems Engineering, is accredited as a nontraditional engineering program by the Accreditation Board for Engineering and Technology, and has received the board's first Award for Curricular Innovation. Because of the overwhelming student demand for the major in recent years, enrollment in the program is limited. Admission is based on space availability, academic performance, and extracurricular activities. Application forms and further information is available in the department office in Olsson 114.

**Minor** Students who wish to minor in systems engineering must satisfactorily complete APMA 310, 312; and four courses from SYS 201, 204, 256, 321, and 360 with a cumulative grade point average of 2.0. Students who wish to pursue a minor in systems must obtain the application form in Thornton A122 and follow the instructions therein.

## Systems Engineering Curriculum (128 credits)

### First Semester

APMA 111	Single Variable Calculus .....	4
CHEM 151	Intro Chem. for Engr.....	3
CHEM 151L	Intro Chemistry Lab .....	1
ENGR 162	Intro to Engineering .....	4
TCC 101	Language Communication & the Technological Society .....	<u>3</u>
		15

### Second Semester

APMA 212	Multivariate Calculus.....	4
PHYS 142E	General Physics I.....	4
CS 101	Intro to Computer Science.....	3
	Science elective I <sup>(1)</sup> .....	3
	HSS elective <sup>(3)</sup> .....	<u>3</u>
		17

### Third Semester

APMA 213	Ordinary Differential Eq.....	4
PHYS 241E	General Physics II.....	3
PHYS 241L	General Physics II Lab .....	1
CS 201	Software Devel. Methods.....	3
SYS 201	Systems Engr. Concepts.....	3
	HSS elective <sup>(3)</sup> .....	<u>3</u>
		17

### Fourth Semester

APMA 310	Probability .....	3
	Science elective II <sup>(2)</sup> .....	3
APMA 308	Linear Algebra .....	3
SYS 202	Data & Information Engr. ....	3

TCC ____	TCC 2xx/3xx elective .....	3
		15

**Fifth Semester**

APMA 312	Statistics.....	3
SYS 321	Network Model & Design.....	3
SYS 323	Human Machine Interface ...	3
SYS 355	SE Design Colloquium I.....	1
	Technical elective <sup>(5)</sup> .....	3
	HSS elective <sup>(3)</sup> .....	3
		16

**Sixth Semester**

SYS 334	System Evaluation.....	3
SYS 360	Probability Models in Business Analysis and Economic Systems .....	3
SYS 362	Discrete Event Simulation....	4
	Application elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		16

**Seventh Semester**

TCC 401	Western Technology and Culture.....	3
SYS 421	Anal. Apps.& Databases....	4
SYS 453	Systems Design I.....	3
SYS 455	SE Design Colloquium II .....	1
	Application elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		17

**Eighth Semester**

TCC 402	The Engineer in Society .....	3
SYS 454	Systems Design II.....	3
	Technical elective <sup>(5)</sup> .....	3
	Application elective <sup>(4)</sup> .....	3
	Unrestricted elective <sup>(6)</sup> .....	3
		15

- (1) Chosen from: BIOL 201, 202; CHEM 152L; MSE 209; and PHYS 242E.
- (2) Chosen from the list of SEAS approved science elective I courses, as well as from any 200 to 400-level science or mathematics course approved for science majors.
- (3) Chosen from the approved list available in A122 Thornton Hall.
- (4) Nine credits of applications electives should be selected in a related applications area of systems engineering. Appropriate sequences include biomedical systems, communications systems, computer and information systems, control systems, economic systems, environmental and water resource systems, management systems, manufacturing systems, mathematical systems, military systems (ROTC), and transportation land-use systems. Students may define alternative application sequences with the advice and consent of their academic advisor.
- (5) Chosen from 200-level (or higher) courses in SEAS, other than TCC.
- (6) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or

any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective for students who do not take APMA 111.

**Division of Technology, Culture, and Communication**

The Division of Technology, Culture, and Communication provides instruction in various studies essential to the professional development of a future engineer or applied scientist. Most prominent of these are skills in oral and written communication, developed through written and audio-visual media, and an understanding of the social, historical, aesthetic, and ethical dimensions of technology.

In addition to the prescribed first- and fourth-year courses (TCC 101, 401-402) required of all School of Engineering and Applied Sciences undergraduates, the division offers an array of 200-level courses from which each student must choose at least one, as well as additional elective courses at the 300 level. These courses deal with the relations between technology and human needs and aspirations, and with the social dimensions of technology-related problems.

The work of the division supplements students' general education (furthered by course work in the College of Arts and Sciences) with their technical studies. It guarantees that students will have seriously considered the moral, social, and environmental consequences of their future life's work.

Graduate courses include seminars in science and society (TCC 501) and advanced scientific writing (TCC 502 and 600).

**Minor in the History of Science and Technology**

While not offering a major, the Division of Technology, Culture, and Communication does offer, in conjunction with the history department, a minor in the history of technology and science. Open to all undergraduates, this minor provides students with an opportunity to become familiar with humanistic perspectives of technology and science. For the engineering student, the minor offers an occasion for placing his or her professional education in a larger social and intellectual context; likewise, it provides the liberal arts student with a better understanding of science and technology as key components in human culture.

**Requirements for the Minor in the History of Science and Technology** The minor consists of 18 credits. College students may include the non-College courses as general electives upon completion of the requirements for the minor. The list of eligible courses and requirements can be obtained

from the Minor Coordinator, Division of Technology, Culture, and Communication, Thornton Hall, Charlottesville, VA 22903; (434) 924-3425.

**Minor in Technology Management and Policy**

The University prepares students to assume leadership roles in both their professions and society at large. In modern society, leadership in any field increasingly depends on an understanding of the processes and consequences of technological change. Moreover, the economic vitality of the commonwealth and the nation depend upon the mastery of complex, science-based technologies.

The minor in Technology Management and Policy (TMP) addresses these concerns with an interdisciplinary course of studies integrating technical knowledge and analytical skills. In bringing multiple disciplinary perspectives to bear on complex issues shaping our nation's future, the program is a vehicle for developing scientific and technological literacy among commerce, government, and liberal arts students, while also expanding the social awareness of engineering and science students.

**Requirements for the Minor in Technology Management and Policy** The six-course minor requires ECON 201, and TMP 351 and 352. The other three courses are selected from a list of electives available in A122 Thornton Hall. The program is administered by a director and coordinating committee appointed by the dean of the school. This committee approves elective courses and projects, and reviews plans of study submitted for fulfillment of the minor.

**Minor in Technology and the Environment**

The increasing prevalence of technology has affected the environment in complex and often unforeseen ways. Society is now demanding that all disciplines of engineering be environmentally aware. Furthermore, those that use and distribute technology need to appreciate its far-ranging impacts. For a more sophisticated understanding of the relationships between technology and the environment, engineers, managers, and historians require interdisciplinary expertise.

This minor, open to all undergraduates, addresses these concerns with an interdisciplinary course of studies. A cornerstone of the minor is a basic knowledge of the technologies that directly impact environmental systems. This technological foundation allows students to build a more sophisticated understanding of how technology and the environment are interrelated. In addition to the technological courses, complementary interdisciplinary courses are selected to complete the minor.

**Requirements for the Minor in Technology and the Environment** The minor consists of six courses (18 credits), with no more than two courses taken in the student's major department. Each student must complete at least two courses related to environmental technology, including either CE 205 or EVSC 148. In addition, each student must choose an emphasis by completing at least three courses in one of three areas: environmental planning and policy, history of technology and the environment, or management and economics. A full description of suitable course work for this minor is available from the minor coordinator in Thornton Hall, (434) 924-6375.

## Course Descriptions

Some courses included in the engineering and applied science curricula are taught by the College of Arts and Sciences faculty and are listed in the course offerings of that school. These include physics (PHYS), chemistry (CHEM), and college mathematics (MATH).

**Note** Courses at the 600 level and above are listed in the *Graduate Record*.

## Applied Mathematics

### APMA 100 - (4) (Y)

**Introduction to Engineering Mathematics**  
Includes algebra, trigonometry, and analytic geometry; emphasizes graphing and attaining proficiency in the manipulation of mathematical expressions. Designed to promote the mathematical maturity necessary for success in calculus. Does not count toward the degree requirements in engineering.

### APMA 109 - (4) (Y)

#### Calculus I

The concepts of differential and integral calculus are developed and applied to the elementary functions of a single variable. Applications are made to problems in analytic geometry and elementary physics. For students with no exposure to high school calculus.

### APMA 110 - (4) (Y)

#### Calculus II

*Prerequisite:* APMA 109 or equivalent

A continuation of APMA 109. Topics include vectors in the plane and in three-space; techniques of integration; indeterminate forms; polar coordinates; and infinite series.

### APMA 111 - (4) (Y)

#### Single Variable Calculus

*Prerequisite:* prior exposure to calculus

Includes the concepts of differential and integral calculus, and applications to problems in geometry and elementary physics, including indeterminate forms and techniques of integration.

### APMA 202 - (3) (S)

#### Discrete Mathematics I

*Prerequisite:* APMA 110 and CS 101, or

equivalent

Introduces discrete mathematics and proof techniques involving first order predicate logic and induction. Application areas include sets (finite and infinite, such as sets of strings over a finite alphabet), elementary combinatorial problems, and finite state automata. Develops tools and mechanisms for reasoning about discrete problems. Cross-listed as CS 202.

### APMA 212 - (4) (S)

#### Multivariate Calculus

*Prerequisite:* APMA 110 or APMA 111

Topics include infinite series; vectors in three-space and vector valued functions; and multivariate calculus, including partial differentiation and multiple integrals.

### APMA 213 - (4) (S)

#### Ordinary Differential Equations

*Prerequisite:* APMA 212

An introduction that includes basic linear algebra, systems of ordinary differential equations, and Laplace transforms.

### APMA 302 - (3) (Y)

#### Discrete Mathematics II

*Prerequisite:* APMA/CS 202 or equivalent

A continuation of APMA 202, consisting of topics in combinatorics, including recurrence relations and generating functions. An introduction to graph theory, including connectivity properties; and Eulerian and Hamiltonian graphs, spanning trees and shortest path problems. Cross-listed as CS 302.

### APMA 308 - (3) (S)

#### Linear Algebra

*Prerequisite:* APMA 212 or equivalent

Analyzes the systems of linear equations; vector spaces; linear dependence; bases; dimension; linear mappings; matrices; determinants; quadratic forms; eigenvalues; orthogonal reduction to diagonal form; and geometric applications.

### APMA 310 - (3) (S)

#### Probability

*Prerequisite:* APMA 212 or equivalent

A calculus-based introduction to probability theory and its applications in engineering and applied science. Includes counting techniques, conditional probability, independence, discrete and continuous random variables, expected value and variance, joint distributions, covariance, correlation, Central Limit theorem, an introduction to stochastic processes.

### APMA 312 - (3) (S)

#### Statistics

*Prerequisite:* APMA 310 or equivalent

Includes confidence interval and point estimation methods, hypothesis testing for single samples, inference procedures for single-sample and two-sample studies, single and multifactor analysis of variance techniques, linear and non-linear regression and correlation, and using Minitab for large data sets.

### APMA 314 - (3) (S)

#### Vector Calculus and Partial Differential Equations

*Prerequisite:* APMA 213

Includes vector integration, boundary value problems, Fourier series, and the solution of the heat, wave, and Laplace's equations by separation of variables.

### APMA 495, 496 - (3) (Y)

#### Independent Reading and Research

*Prerequisite:* fourth-year standing

Reading and research under the direction of a faculty member.

### APMA 507 - (3) (SI)

#### Numerical Methods

*Prerequisite:* two years of college mathematics, including some linear algebra and differential equations, and the ability to write computer programs in any language

Introduces techniques used in obtaining numerical solutions, emphasizing error estimation. Includes approximation and integration of functions, and solution of algebraic and differential equations.

## Biomedical Engineering

### BIOM 301 - (3) (Y)

#### Physiology I

*Prerequisite:* CHEM 151, PHYS 241E and BIOL 201, or instructor permission

Studies how excitable tissue, nerves and muscle, and the cardiovascular and respiratory systems work. Focuses on understanding mechanisms, and includes an introduction to structure, an emphasis on function, and integration of hormonal and neural regulation and control.

### BIOM 304 - (3) (Y)

#### Cell and Molecular Biology for Engineers

*Prerequisite:* CHEM 151 and BIOL 201, or instructor permission

Introduces the fundamentals of cell structure and function, emphasizing the techniques and technologies available for the study of cell biology. Divided into three general sections: cell structure and function includes cell chemistry, organelles, enzymes, membranes, membrane transport, intracellular compartments and adhesion structures; energy flow in cells concentrates on the pathways of glycolysis and aerobic respiration; information flow in cells focuses on modern molecular biology and genetic engineering, and includes DNA replication, the cell cycle, gene expression, gene regulation, and protein synthesis. Also presents specific cell functions, including movement, the cytoskeleton and signal transduction.

### BIOM 411 - (3) (Y)

#### Bioinstrumentation and Design

*Prerequisite:* ECE 203 or MAE 202, or instructor permission

Introduces transducers and instrumentation systems used in measuring biological vari-

ables. Discusses the physical, electromagnetic, and chemical principles of measurement, effects of interfaces between biological systems and sensors, and design tradeoffs. Surveys major electronic circuits and signal conditioning systems for biological and medical monitoring. Laboratory experiments involve construction and characterization of simple transducers, imaging systems, and signal conditioning equipment for biological variables, such as blood pressure, displacement, force, temperature, flow, and biopotentials. Exercises cover conceptual design to detailed design specifications for selected biomedical instrumentation systems.

### **BIOM 422 - (3) (Y)**

#### **Biomechanics**

*Prerequisite:* APMA 212, 213, and BIOM 301, or instructor permission

Introduces principles of mechanics, with applications to biological tissues and systems. Includes statics, dynamics, free-body diagrams, constitutive equations of biological materials including biofluids, biosolids, and viscoelastic structures, and strength of materials. Presents properties of blood vessels, bone, muscle, skin, cartilage, ligaments, tendons, and other tissues. Investigates mechanical basis and effects of pathology and trauma, applications to medical diagnosis and therapy.

### **BIOM 428 - (3) (SI)**

#### **Motion Biomechanics**

Focuses on the study of forces (and their effects) that act on the musculoskeletal structures of the human body. Based on the foundations of functional anatomy and engineering mechanics (rigid body and deformable approaches); students are exposed to clinical problems in orthopedics and rehabilitation.

### **BIOM 441 - (3) (SI)**

#### **Bioelectricity**

*Prerequisite:* ECE 203 or MAE 202; BIOM 301, or instructor permission

Studies the biophysical mechanisms governing production and transmission of bioelectric signals, measurement of these signals and their analysis in basic and clinical electrophysiology. Introduces the principles of design and operation of therapeutic medical devices used in the cardiovascular and nervous systems. Includes membrane potential, action potentials, channels and synaptic transmission, electrodes, electroencephalography, electromyography, electrocardiography, pacemakers, defibrillators, and neural assist devices.

### **BIOM 453, 454 - (3) (Y)**

#### **Advanced Projects**

*Prerequisite:* fourth-year standing

A year-long research project in biomedical engineering conducted in consultation with a department faculty advisor; usually related to ongoing faculty research. Includes the design, execution, and analysis of experimental laboratory work and computational or theoretical

computer analysis of a problem. Requires a comprehensive report of the results.

### **BIOM 483 - (3) (Y)**

#### **Medical Image Modalities**

Studies engineering and physical principles underlying the major imaging modalities such as X-ray, ultrasound CT, MRI, and PET. A comprehensive overview of modern medical imaging modalities with regard to the physical basis of image acquisition and methods of image reconstruction. Students learn about the tradeoffs, which have been made in current implementations of these modalities. Considers both primarily structural modalities (magnetic-resonance imaging, electrical-impedance tomography, ultrasound, and computer tomography) and primarily functional modalities (nuclear medicine, single-photo-emission computed tomography, positron-emission tomography, magnetic-resonance spectroscopy, and magnetic-source imaging).

### **BIOM 484 - (4) (SI)**

#### **Medical Image Analysis**

*Prerequisite:* ECE 323 or instructor permission

Introduces the fundamental principles of medical image analysis and visualization. Focuses on the processing and analysis of ultrasound, MR, and X-ray images for the purpose of quantitation and visualization to increase the usefulness of modern medical image data. Includes image perception and enhancement, 2-D Fourier transform, spatial filters, segmentation, and pattern recognition. A weekly lab develops skill in computer image analysis with the KHOROS system.

### **BIOM 495, 496 - (3) (SI)**

#### **Special Topics in Biomedical Engineering**

*Prerequisite:* fourth-year standing and instructor permission

Applies engineering science, design methods, and system analysis to developing areas and current problems in biomedical engineering. Topics vary by semester.

## **Chemical Engineering**

### **CHE 202 - (3) (S)**

#### **Thermodynamics**

*Prerequisite:* APMA 111

Includes the formulation and analysis of the first and second laws of thermodynamics; energy conservation; concepts of equilibrium, temperature, energy, and entropy; equations of state; processes involving energy transfer as work and heat; reversibility and irreversibility; and closed and open systems and cyclic processes. Three lecture and one laboratory/ workshop hour. Cross-listed as MAE 210.

### **CHE 215 - (3) (Y)**

#### **Material and Energy Balances**

*Prerequisite:* CHEM 151, APMA 111

Introduces the field of chemical engineering, including material and energy balances applied to chemical processes, physical and thermodynamic properties of multicomponent systems. Three lecture and one discussion hour.

### **CHE 216 - (3) (Y)**

#### **Modeling and Simulation in Chemical Engineering**

*Prerequisite:* CS 101, CHE 215, APMA 213

Computational tools for analysis and simulation of chemical processes and physicochemical phenomena. Statistical analysis and regression, numerical methods, process simulation programs. Three lecture and one laboratory hour.

### **CHE 316 - (3) (Y)**

#### **Chemical Thermodynamics**

*Prerequisite:* CHE 202 or equivalent

Principles of chemical thermodynamics further developed and applied. Emphasizes phase and chemical equilibria calculations. Three lecture hours.

### **CHE 318 - (3) (Y)**

#### **Chemical Reaction Engineering**

*Prerequisite:* CHEM 151, 152, CHE 215, 216, APMA 213; *corequisite:* CHE 322

Determination of rate equations for chemical reactions from experimental data. Use of kinetics and transport relations in the design of both batch and continuous reactors; homogeneous, heterogeneous, uncatalyzed and catalyzed reactions. Three lecture hours.

### **CHE 321 - (4) (Y)**

#### **Transport Processes I: Momentum and Heat Transfer**

*Prerequisite:* CHE 215, 216, and APMA 213

Development and application of the concepts of momentum and heat transfer to chemical processing operations, emphasizing continuous operations. Four lecture hours.

### **CHE 322 - (4) (Y)**

#### **Transport Processes II: Mass Transfer and Separations**

*Prerequisite:* CHE 216, 316, and 321

Fundamental concepts of diffusion and mass transfer. Application to continuous contacting in separation devices. Material and energy conservation calculations for equilibrium stage processes, including multistage, multicomponent calculations as involved in distillation, absorption, and extraction systems. Four lecture hours.

### **CHE 398 - (3) (Y)**

#### **Chemical Engineering Laboratory I**

*Prerequisite:* CHE 215 and 321

Experimental study of selected operations and phenomena in fluid mechanics and heat transfer. Students plan experiments, analyze data, calculate results and prepare written and/or oral planning and final technical reports. One hour discussion, four laboratory hours.

**CHE 438 - (3) (Y)****Process Modeling, Dynamics, and Control**

*Prerequisite:* CHE 318 and 322

Introduces the dynamics and control of process systems, controller, sensors, and final control elements. Time and frequency domain characterization of these subsystems are developed and employed in stability analysis of closed control loops. Design of simple process control systems. Three lecture hours.

**CHE 442 - (3) (Y)****Applied Surface Chemistry**

*Prerequisite:* instructor permission

Factors underlying interfacial phenomena, emphasizing thermodynamics of surfaces, structural aspects, and electrical phenomena. Application to areas such as emulsification, foaming, detergency, sedimentation, fluidization, nucleation, wetting, adhesion, flotation, and electrophoresis. Three lecture hours.

**CHE 447 - (3) (Y)****Biochemical Engineering**

*Prerequisite:* instructor permission

Introduces the properties, production, and use of biological molecules of importance to medicine and industry, such as proteins, enzymes, and antibiotics. Topics include fermentation and cell culture processes, biological mass transfer, enzyme engineering, and purification techniques. The implications of recent advances in molecular biology, genomics, and proteomics will be considered. Three lecture hours.

**CHE 449 - (3) (Y)****Polymer Chemistry and Engineering**

*Prerequisite:* CHE 321 or instructor permission

Analyzes the mechanisms and kinetics of various polymerization reactions; relations between the molecular structure and polymer properties, and how these properties can be influenced by the polymerization process; fundamental concepts of polymer solution and melt rheology. Application of these principles to polymer processing operations, such as extrusion, molding, and fiber spinning. Three lecture hours.

**CHE 461, 462 - (3) (SI)****Special Topics in Chemical Engineering**

*Prerequisite:* fourth-year standing and instructor permission

Applies engineering science, design methods, and system analysis to developing areas and current problems in chemical engineering. Topics are announced at registration.

**CHE 476 - (3) (Y)****Chemical Engineering Design**

*Prerequisite:* CHE 216, 318, and 322

Application of academically acquired skills to the practice of chemical engineering in an industrial environment: industrial economics; process synthesis and selection; flow

sheet development; equipment sizing; plant layout and cost estimation. Report preparation and oral presentations. Use of commercial process simulation software. Two lecture hours, two discussion hours, and design laboratory.

**CHE 491 - (3) (Y)****Chemical Engineering Laboratory II**

*Prerequisite:* CHE 318, 322, and 398

Continuation of CHE 398; emphasizes separations, chemical reaction, and process dynamics and control. One discussion and four laboratory hours.

**CHE 495, 496 - (1-3) (S)****Chemical Engineering Research**

*Prerequisite:* instructor permission

Library and laboratory study of an engineering or manufacturing problem conducted in close consultation with a departmental faculty member, often including the design, construction, and operation of laboratory scale equipment. Requires progress reports and a comprehensive written report.

**Chemistry****CHEM 151, 152 - (3) (Y)****Introductory Chemistry for Engineers**

*Corequisite:* CHEM 151L and 152L; or CHEM 181L and 182L

Develops the principles and applications of chemistry. Topics include stoichiometry, chemical equations and reactions, chemical bonding, states of matter, thermochemistry, chemical kinetics, equilibrium, acids and bases, electrochemistry, nuclear chemistry, and descriptive chemistry of the elements. Designed for engineering students and may be used as a prerequisite for further courses in chemistry. Three class hours.

**CHEM 151L, 152L - (1) (Y)****Introductory Chemistry for Engineers Laboratory**

*Corequisite:* CHEM 151 and 152

Investigates the practice of chemistry as an experimental science; the development of skills in laboratory manipulation; laboratory safety; observation, measurement, and data analysis; separation and purification techniques; and qualitative and quantitative analysis. Three and one-half laboratory hours. Meets every other week.

**CHEM 212 - (3) (Y)****Introduction to Organic Chemistry**

*Prerequisite:* one semester of general chemistry; *corequisite:* CHEM 212L

Introduces the nomenclature, structure, reactivity, and applications of organic compounds, including those of importance in the chemical industry. Three lecture hours.

**CHEM 212L - (1) (Y)****Introduction to Organic Chemistry Laboratory**

*Corequisite:* CHEM 212

Six-to-seven four-hour laboratory sessions

and an equal number of one-hour laboratory lectures to accompany CHEM 212.

**Civil Engineering****CE 205 - (3) (Y)****Introduction to Environmental Engineering**

Focuses on society's interaction with water, air, and soil systems. Management of these major environmental components is examined, considering health and ecological needs and technical limitations. This course may stand alone as introduction to the current environmental challenges that we face, or as the foundation for further study in the field of environmental engineering.

**CE 206 - (4) (Y)****Solid Mechanics**

Topics include the basic concepts mechanics; systems of forces and couples; equilibrium of particles and rigid bodies; analysis of structures: trusses, frames, machines and beams, centroids and moments of inertia; concepts of stress and strain; constitutive relations; axially loaded members; torsion of circular bars; internal forces in beams; stresses and deformations in beams; analysis of stress and strain; failure theories; and the buckling of columns. Cross-listed as MAE 231.

**CE 207 - (3) (Y)****Dynamics**

*Prerequisite:* PHYS 142E and CE 206

Reviews kinematics and kinetics of particles and the kinematics of rigid bodies, including translation and fixed-axis rotation relative to translating axes; general planar motion; fixed point rotation; and general motion and the kinetics of rigid bodies, specifically center of mass, mass moment of inertia, product of inertia, principal-axes, parallel axis theorems, planar motion, and the work-energy method. Cross-listed as MAE 232.

**CE 209 - (3) (Y)****Probability and Statistics**

*Prerequisite:* APMA 212

This course presents an applied introduction to the use of probability and statistics in civil engineering. The course is intended to prepare students to effectively work with uncertainty in civil engineering systems, and to gain experience in interpreting and analyzing data collected from such systems. The course will address core probability and statistics areas such as probability density functions, data description, inference (confidence intervals and hypothesis tests), model development, and design of experiments. The course will serve as a foundation for higher-level civil engineering courses, research, and design projects.

**CE 241 - (3) (Y)****Civil Engineering Systems Analysis and Statistics**

Introduces the tools of engineering economy,

probability and statistics as applied to civil engineering problems, including problem formulation, economic analysis.

### **CE 315 - (3) (Y)**

#### **Fluid Mechanics**

*Prerequisite:* CE 206 or equivalent

Studies the statics and dynamics of incompressible fluids, primarily water. The basic principles of fluid flow, energy equation, and momentum equation, are presented and applied to closed conduit flow, open channel flow, and problems of flow measurement pertinent to civil engineering practices.

### **CE 316 - (4) (Y)**

#### **Introduction to Geotechnical Engineering**

*Prerequisite:* CE 206

Introduces the fundamental principles of particulate mechanics with an emphasis on soil strength, consolidation behavior, and fluid flow. Concepts of theoretical soil mechanics and soil physics combined with laboratory investigation of soil behavior. Three lecture and three laboratory hours.

### **CE 319 - (3) (Y)**

#### **Structural Mechanics**

*Prerequisite:* CE 206

Fundamentals of structural mechanics: equilibrium compatibility, determinacy, stability; mathematical models of structural elements: stress resultants in bars, beams, and framed structures; calculation of deflections; general analysis of structures: concepts of stiffness and flexibility, force and displacement methods of analysis.

### **CE 323 - (3) (Y)**

#### **Properties and Behavior of Materials**

*Prerequisite:* CE 206

Studies the properties and behavior of engineering materials, emphasizing construction materials, including metals, concrete, wood, and composites. Considers service conditions and underlying scientific principles related to applications and performance of materials.

### **CE 326 - (3) (Y)**

#### **Design of Concrete Structures**

*Prerequisite:* CE 319

Introduces physical properties of concrete and reinforcing steel. Design and analysis of basic structural elements of reinforced concrete including beams, slabs, columns, and footings. Consideration of construction practices and building codes.

### **CE 336 - (3) (Y)**

#### **Water Resources Engineering**

*Prerequisite:* CE 315

Principles of fluid mechanics and hydrology, including open channel and groundwater flow, rainfall, evaporation, and surface runoff applied to water resources development and management. Applications include water supply, drainage, flood control, and water control, emphasizing computer simulation tools.

### **CE 341 - (3) (Y)**

#### **Civil Engineering Systems Analysis**

Introduces the tools of operations research and engineering economy as applied to civil engineering problems; problem formulation, linear programming, economic analysis, and decision analysis; optimization, minimum cost and utility methods; and application to structural optimization, traffic flow, resource allocation and environmental design.

### **CE 344 - (3) (Y)**

#### **Transportation Engineering I**

*Prerequisite:* third-year standing

Analyzes of the characteristics of the driver, pedestrian, vehicle, and road; highway surveys and locations; geometric design, horizontal and vertical alignment of highway cross sections, highway drainage and drainage structures; and highway pavement design.

### **CE 363 - (1) (Y)**

#### **Materials Laboratory**

*Corequisite:* CE 323

Laboratory study of the macroscopic mechanical, thermal, and time-dependent properties and behaviors of typical civil engineering construction materials (metals, concrete, wood, plastics). Students plan and conduct experiments, and prepare written reports.

### **CE 364 - (1) (Y)**

#### **Structural Engineering Laboratory**

*Prerequisite:* CE 319; *corequisite:* CE 326 or 401

Introduces the experimental behavior of common structural configurations, such as beams, trusses, and frames. Exposes students to actual structural behavior and experimentally demonstrates the validity of assumptions made in analysis and design.

### **CE 365 - (1) (Y)**

#### **Fluid Mechanics Laboratory**

*Corequisite:* CE 315

Laboratory study of the flow of fluids. Six experiments are conducted: hydrostatics, jet impact, weir, orifice, Venturi meter, and pipe flow. Uses laboratory data to quantify hydrostatic pressure and force, force due to momentum impact, and flow rates. Also determines friction losses in pipe networks.

### **CE 401 - (3) (Y)**

#### **Design of Metal Structures I**

Analyzes the behavior and design of tension, compression, and flexural members in metal, and the behavior and design of bolted and welded connections. Applies AISC Load and Resistance Factor Design (LRFD) specification for use of structural steel in buildings.

### **CE 402 - (3) (Y)**

#### **Design of Metal Structures II**

Analyzes the behavior and design of continuous beams, plate girders, composite steel-concrete members, members subjected to combined bending and compression, and eccentric connections using LRFD design

approach; and torsion and torsional stability of structural members.

### **CE 403 - (3) (Y)**

#### **Advanced Reinforced Concrete Design**

*Prerequisite:* CE 326

Design of building and bridge components, including floor systems, rigid frames, retaining walls, and tanks. Introduction to prestressed concrete.

### **CE 404 - (3) (SI)**

#### **Advanced Concrete Technology**

Topics include the fundamentals of concrete: ingredients, hydration, and proportioning; production of concrete: batching, transport, finishing, curing, testing, and inspection; special types of concrete: high-performance, fiber-reinforced, roller compacted, polymer, shrinkage compensating, structural lightweight, and shotcrete; and design and code provisions: working stress and ultimate strength design, and provisions of ACI code.

### **CE 411 - (3) (Y)**

#### **Foundation Engineering**

*Prerequisite:* CE 316 and 326 or CE 401

Analyzes the methods and purposes of subsurface exploration; control of ground water; excavations; sheeting and bracing design; shallow foundations; bearing capacity and settlement analysis; deep foundation—piles, piers, caissons and cofferdams; underpinning; and the legal aspects of foundation engineering.

### **CE 420 - (3) (Y)**

#### **Experimental Analyses in Environmental Engineering**

*Prerequisite:* CHEM 151/151L, APMA 213, CE 315, or equivalent

Increases familiarity with the theory and implementation of laboratory, computational, and field procedures common to environmental engineering. Weekly in-class laboratories alternate between hands-on-laboratory, field, or computer experiments, and demonstrations of advanced analytical instrumentation or field sampling procedures. Weekly lectures provide the theoretical background that pertains directly to the laboratory for that week. Topics covered are relevant to water and wastewater treatment operations, ground- and surface-water hydrology, and the fate and transport of pollutants in the environment.

### **CE 430 - (3) (Y)**

#### **Environmental Engineering**

*Prerequisite:* CE 315

Analyzes the design of unit processes used to control the quality of water and waste water associated with people and the environment. Process considerations include pump systems, mixing, sedimentation, filtration, precipitation, coagulation, disinfection, and biological oxidation. Presents principles of design and design practices used in physical, chemical, and biological treatment are presented.

**CE 440 - (3) (Y)****Groundwater Hydrology**

*Prerequisite:* CS 101, CE 315, CE 336 or equivalent

Topics include Darcy's Law, fluid potential, hydraulic conductivity, heterogeneity and anisotropy, the unsaturated zone, compressibility, transmissivity and storativity, the 3-D equation of groundwater flow, steady-state and transient regional groundwater flow, and well hydraulics, including discussions involving Theis' Inverse Method, Jacob's Method, slug test analyses, and the principle of superposition. Introduces computer simulation of groundwater flow using the finite-difference method. Requires computer programming using FORTRAN, C++, or equivalent.

**CE 441 - (3) (Y)****Construction Engineering and Economics**

*Prerequisite:* CE 206

Legal and commercial aspects of the relation between owner, engineer, architect, and contractor. Salient features of labor law affecting the construction industry. Job planning and scheduling construction stages and operations. Depreciation, replacements, comparison of alternate proposals, and calculation of prospective rate of return. Design of material handling facilities and theoretical analysis of construction equipment performance. SEAS students cannot receive degree credit for both CE 441 and ARCH 534.

**CE 444 - (3) (Y)****Transportation Engineering II**

*Prerequisite:* CE 344 or instructor permission

Analyzes traffic characteristics: the road user, the vehicle and roadway; traffic engineering studies: speed, volume, and delay; and intersection control, capacity, and level of service.

**CE 445 - (3) (Y)****Transportation Engineering III**

*Prerequisite:* graduate standing or CE 344; or instructor permission

Framework and principles of urban transportation planning; transportation decision making; transportation data and information systems; analysis and evaluation of alternatives; forecasts of population and socioeconomic activity; small area land use allocation; introduction to supply-demand equilibrium, trip generation, trip distribution, modal choice, traffic assignment; quick response model applications.

**CE 446 - (3) (Y)****Introduction to Geographic Information Systems**

Introduces engineering problem-solving using geographic information systems (GIS). GIS has proven to be an effective tool in Civil Engineering applications that include a significant spatial component. Focuses on the fundamental concepts of GIS, the top-down process required to effectively use advanced

information technology tools, and the acquisition of hands-on experience in GIS problem-solving using the ArcView GIS package. Provides experience with the GIS application process, rather than expertise in a particular GIS software package.

**CE 451, 452 - (3) (SI)****Special Topics in Civil Engineering**

*Prerequisite:* fourth-year standing and instructor permission

Applies basic engineering principles, analytical procedures and design methodology to special problems of current interest in civil engineering. Topic(s) for each semester are announced at the time of course enrollment.

**CE 455 - (3) (Y)****Mechanics of Composite Materials**

*Prerequisite:* CE 206

Introduces engineering properties and advantages of advanced fibrous composites; anisotropic, thermo-mechanical constitutive theory for plane stress analysis; thermo-mechanical stress analysis of laminates subjected to inplane and bending loads; engineering properties of laminates; test methods and material response (in the laboratory); designing with composites; computer implementation. Cross-listed as MAE 454.

**CE 461 - (3) (Y)****Computer Applications in Civil Engineering**

*Prerequisite:* fourth-year standing

Studies civil engineering problems and their solutions in a numerical context, using the digital computer; the formulation of these problems using various computational procedures; the development of typical algorithms; utilization of microcomputers, including structured programming with graphics. Emphasizes construction of numerical models for applications and the solution of representative multidimensional problems from all areas of civil engineering.

**CE 462 - (3) (Y)****Advanced Structural Analysis**

*Prerequisite:* CE 319

The general methods of analyzing indeterminate structures; fundamentals of structural theory, including virtual work and energy theorems; introduction to concepts of stiffness and flexibility; force and displacement methods of analysis, methods of consistent deformation, slope-deflection, moment distribution; and an introduction to matrix formulation.

**CE 471 - (3) (Y)****Introduction to Finite Element Methods**

*Prerequisite:* CE 319

Review of matrix operations. Introduces basic concepts of finite element analysis. Weighted residual (Galerkin) approach and variational (Rayleigh-Ritz) approach. One-

dimensional and two-dimensional formulations; local vs. global coordinate systems; shape functions. Computational implementation and applications in the areas of structural analysis, steady-state fluid flow, and heat transfer.

**CE 490 - (3) (Y)****Civil Engineering Design and Practice**

*Prerequisite:* Fourth-year status

This course will broaden a student's exposure to professional practice issues, including project planning and management, financial and contractual relationships. The major focus of the course will be providing practical civil engineering design experience. Students will participate in one or more multi-disciplinary team design projects requiring integration of technical skills from multiple sub-areas of civil engineering (structural, environmental and transportation systems) and application of managerial skills. Extension of design projects to undergraduate thesis projects is encouraged.

**CE 495, 496 - (1-3) (SI)****Civil Engineering Research**

*Prerequisite:* fourth-year standing

Study of a civil engineering problem in depth by each student using library, computer, or laboratory facilities. The project is conducted in close consultation with departmental faculty and involves survey, analysis, or project development. Progress reports and a comprehensive written report are required. May be repeated if necessary.

**Computer Science****CS 101 - (3) (S)****Introduction to Computer Science**

Introduces the basic principles and concepts of object-oriented programming through a study of algorithms, data structures and software development methods. Emphasizes both synthesis and analysis of computer programs.

**CS 110 - (3) (S)****Introduction to Information Technology**

Provides exposure to a variety of issues in information technology, such as computing ethics and copyright. Introduces and provides experience with various computer applications, including e-mail, newsgroups, library search tools, word processing, Internet search engines, and HTML. Not intended for students expecting to do further work in CS. Cannot be taken for credit by students in SEAS or Commerce.

**CS 120 - (3) (S)****Introduction to Business Computing**

Overview of modern computer systems and introduction to programming in Visual Basic, emphasizing development of programming skills for business applications. Intended primarily for pre-commerce students. May not be taken for credit by students in SEAS.

**CS 201 - (3) (S)****Software Development Methods**

*Prerequisite:* CS 101 with a grade of C- or higher

A continuation of CS 101, emphasizing modern software development methods. An introduction to the software development life cycle and processes. Topics include requirements analysis, specification, design, implementation, and verification. Emphasizes the role of the individual programmer in large software development projects.

**CS 202 - (3) (Y)****Discrete Mathematics I**

*Prerequisite:* CS 101 or equivalent with grade of C- or higher

Introduces discrete mathematics and proof techniques involving first order predicate logic and induction. Application areas include sets (finite and infinite), elementary combinatorial problems, and finite state automata. Development of tools and mechanisms for reasoning about discrete problems. Cross-listed as APMA 202.

**CS 216 - (3) (Y)****Program and Data Representation**

*Prerequisite:* CS 201 and 202 with grades of C- or higher

Introduces programs and data representation at the machine level. Data structuring techniques and the representation of data structures during program execution. Operations and control structures and their representation during program execution. Representations of numbers, arithmetic operations, arrays, records, recursion, hashing, stacks, queues, trees, graphs, and related concepts.

**CS 230 - (3) (S)****Digital Logic Design**

Includes number systems and conversion; Boolean algebra and logic gates; minimization of switching functions; combinational network design; flip-flops; sequential network design; arithmetic networks; introduction to computer organization and assembly language. Five laboratory assignments. Cross-listed as ECE 230.

**CS 302 - (3) (Y)****Discrete Mathematics II**

*Prerequisite:* CS 202 or equivalent with a grade of C+ or higher or instructor permission

Continuation of CS 202, consisting of topics in combinatorics, including recurrence relations and generating functions. Introduces computation theory including grammars, finite state machines and Turing machines; and graph theory, including connectivity properties, Eulerian and Hamiltonian graphs, spanning trees and shortest path problems. Cross-listed as APMA 302.

**CS 305 - (3) (Y)****Usability Engineering**

*Prerequisite:* CS 101 with a grade of C- or

higher, or instructor permission

Focuses on the interface between humans and all technology, not just humans and computers. Treats human usability as an engineering design goal. Designs user interfaces to technology.

**CS 332 - (3) (Y)****Algorithms**

*Prerequisite:* CS 216 and 302 with grades of C- or higher

Introduces the analysis of algorithms and the effects of data structures on them. Algorithms selected from areas such as sorting, searching, shortest paths, greedy algorithms, backtracking, divide-and-conquer, and dynamic programming. Data structures include heaps and search, splay, and spanning trees. Analysis techniques include asymptotic worst case, expected time, amortized analysis, and reductions between problems.

**CS 333 - (3) (S)****Computer Architecture**

*Prerequisite:* CS 201 and EE/CS 230 with grades of C- or higher

Includes the organization and architecture of computer systems hardware; instruction set architectures; addressing modes; register transfer notation; processor design and computer arithmetic; memory systems; hardware implementations of virtual memory, and input/output control and devices. Cross-listed as EE 333.

**CS 340 - (3) (Y)****Advanced Software Development Techniques**

*Prerequisite:* CS 216 with a grade of C+ or higher or permission of instructor

Analyzes modern software engineering practice for multi-person projects; methods for requirements specification, design, implementation, verification, and maintenance of large software systems; advanced software development techniques and large project management approaches; project planning, scheduling, resource management, accounting, configuration control, and documentation.

**CS 390 - (1) (Y)****Computer Science Seminar I**

*Prerequisite:* third-year CS majors only

A "cultural capstone" to the undergraduate experience. Students make presentations based on topics not covered in the traditional curriculum. Emphasizes learning the mechanisms by which researchers and practicing computer scientists can access information relevant to their discipline, and on the professional computer scientist's responsibility in society.

**CS 414 - (3) (Y)****Operating Systems**

*Prerequisite:* CS 216 and 333 with grades of C- or higher

Analyzes process communication and syn-

chronization; resource management; virtual memory management algorithms; file systems; and networking and distributed systems.

**CS 415 - (3) (Y)****Programming Languages**

*Prerequisite:* CS 216 and 333 with grades of C- or higher

Presents the fundamental concepts of programming language design and implementation. Emphasizes language paradigms and implementation issues. Develops working programs in languages representing different language paradigms. Many programs oriented toward language implementation issues.

**CS 416 - (3) (Y)****Artificial Intelligence**

*Prerequisite:* CS 201 and 202 with grades of C- or higher

Introduces artificial intelligence. Covers fundamental concepts and techniques and surveys selected application areas. Core material includes state space search, logic, and resolution theorem proving. Application areas may include expert systems, natural language understanding, planning, machine learning, or machine perception. Provides exposure to AI implementation methods, emphasizing programming in Common LISP.

**CS 434 - (3) (Y)****Fault-tolerant Computing**

*Prerequisite:* CS 333, APMA 213, 310 with grades of C- or higher

Investigates techniques for designing and analyzing dependable computer-based systems. Topics include fault models and effects, fault avoidance techniques, hardware redundancy, error detecting and correcting codes, time redundancy, software redundancy, combinatorial reliability modeling, Markov reliability modeling, availability modeling, maintainability, safety modeling, trade-off analysis, design for testability, and the testing of redundant digital systems. Cross-listed as ECE 434.

**CS 445 - (3) (Y)****Introduction to Computer Graphics**

*Prerequisites:* CS 216 (Data Structures) or instructor permission

This course will introduce the fundamentals of three-dimensional computer graphics: rendering, modeling, and animation. Students will learn how to represent three-dimensional objects (modeling) and the movement of those objects over time (animation). Students will learn and implement the standard rendering pipeline, defined as the stages of turning a three-dimensional model into a shaded, lit, texture-mapped two-dimensional image.

**CS 453 - (3) (Y)****Electronic Commerce Technologies**

*Prerequisite:* CS 340 or equivalent programming maturity

History of Internet and electronic commerce on the WWW; case studies of success and failure; cryptographic techniques for privacy, security, and authentication; digital money; transaction processing; wired and wireless access technologies; Java; streaming multimedia; XML; Bluetooth. Defining, protecting, growing, and raising capital for an e-business.

**CS 457 - (3) (Y)**

**Computer Networks**

*Prerequisite:* CS 333 with grade of C- or higher

Intended as a first course in communication networks for upper-level undergraduate students. Topics include the design of modern communication networks; point-to-point and broadcast network solutions; advanced issues such as Gigabit networks; ATM networks; and real-time communications. Cross-listed as ECE 457.

**CS 458 - (3) [1 hour lab] (Y)**

**Internet Engineering**

*Prerequisite:* CS 457 or EE 457

An advanced course on computer networks on the technologies and protocols of the Internet. Topics include the design principles of the Internet protocols, including TCP/IP, the Domain Name System, routing protocols, and network management protocols. A set of laboratory exercises covers aspects of traffic engineering in a wide-area network.

**CS 462 - (3) (Y)**

**Database Systems**

*Prerequisite:* CS 202 and 216 with grades of C- or higher

Introduces the fundamental concepts for design and development of database systems. Emphasizes relational data model and conceptual schema design using ER model, practical issues in commercial database systems, database design using functional dependencies, and other data models. Develops a working relational database for a realistic application.

**CS 493 - (1-3) (S)**

**Independent Study**

*Prerequisite:* instructor permission

In-depth study of a computer science or computer engineering problem by an individual student in close consultation with departmental faculty. The study is often either a thorough analysis of an abstract computer science problem or the design, implementation, and analysis of a computer system (software or hardware).

**CS 494 - (1-3) (S)**

**Special Topics in Computer Science**

*Prerequisite:* instructor permission, additional specific requirements vary with topics. Content varies annually, depending on instructor interests and the needs of the department. Similar to CS 551 and 751, but taught strictly at the undergraduate level.

**CS 551 - (1-3) (S)**

**Selected Topics in Computer Science**

*Prerequisite:* instructor permission

Content varies annually, depending on students' needs and interests. Recent topics included the foundations of computation, artificial intelligence, database design, real-time systems, Internet engineering, and electronic design automation.

**CS 571 - (3) (Y)**

**Translation Systems**

*Prerequisite:* CS 340 and 333 with grades of C- or higher

The theory, design, and specification of translation systems. Translation systems are the tools used to translate a source language program to a form that can be executed. Students design, specify, and implement various translators by applying classical translation theory using rigorous specification techniques to describe the inputs and outputs of the translators.

**CS 586 - (3) (Y)**

**Real Time Systems**

*Prerequisites:* CS 333 and CS 414 with a grade of C+ or higher, knowledge of C or C++, or instructor permission

This course presents the underlying theory, concepts, and practice for real-time systems, such as avionics, process control, space travel, mobile computing and ubiquitous computing. The goals of the course include: introducing the unique problems that arise when time constraints are imposed on systems, identifying basic theory and the boundary between what is known today and what is still research, stressing a systems integration viewpoint in the sense of showing how everything fits together rather than presenting a collection of isolated solutions, and addressing multiprocessing and distributed systems. This course also presents some of the basic results from what might be called the classical technology of real-time computing and presents these results in the context of new applications of this technology in ubiquitous/pervasive computer systems.

**CS 587 - (3) (Y)**

**Security in Information Systems**

*Prerequisites:* CS 340 and either CS 457 or CS 414 with a grade of C+ or higher, or instructor permission

This course focuses on security as an aspect of a variety of software systems. We will consider software implementations of security related policies in the context of operating systems, networks, and data bases. Topics include: operating system protection mechanisms, intrusion detection systems, formal models of security, cryptography and associated security protocols, data base security, worms, viruses, network and distributed system security, and policies of privacy and confidentiality.

**CS 588 - (3) (Y)**

**Cryptology: Principles and Applications**

*Prerequisites:* CS 302 with a grade of C+ or higher, or instructor permission

Introduces the basic principles and mathematics of cryptology including information theory, classical ciphers, symmetric key cryptosystems and public-key cryptosystems. Develops applications of cryptology such as anonymous email, digital cash and code signing.

**Electrical and Computer Engineering**

**ECE 200 - (3) (S)**

**Science of Information**

An introduction to the fundamental scientific principles governing information science and engineering. Topics include: definition of information; entropy; information representation in analog and digital forms; information transmission; spectrum and bandwidth; information transformation including data compression, filtering, encryption, and error correction; information storage and display; and large-scale information systems. Technologies for implementing information functions. Three credit hours.

**ECE 203 - (3) (S)**

**Introductory Circuit Analysis**

*Prerequisite:* APMA 111

Includes elementary electric circuit concepts and their application to linear circuits with passive elements; use of Kirchhoff's voltage and current laws to derive circuit equations; solution methods for first- and second-order transient and DC steady-state responses; AC steady-state analysis; frequency domain representation of signals; trigonometric and complex Fourier series; phasor methods; transfer functions and resonance; Thevenin/Norton equivalent models; and controlled sources. Six laboratory assignments.

**ECE 204 - (4) (Y)**

**Electronics I**

*Prerequisite:* ECE 203

Studies the modeling, analysis, design, computer simulation, and measurement of electrical circuits which contain non-linear devices such as junction diodes, bipolar junction transistors, and field effect transistors. Includes the gain and frequency response of linear amplifiers, power supplies, and other practical electronic circuits. Three lecture and three laboratory hours.

**ECE 230 - (3) (S)**

**Digital Logic Design**

Includes number systems and conversion; Boolean algebra and logic gates; minimization of switching functions; combinational network design; flip-flops; sequential network design; arithmetic networks. Introduces computer organization and assembly language.

Five laboratory assignments. Cross-listed as CS 230.

### **ECE 303 - (3) (Y)**

#### **Solid State Devices**

*Prerequisite:* PHYS 252, ECE 203, or MAE 202

Analyzes the basics of band theory and atomic structure; charge-transport in solids; current voltage characteristics of semiconductor devices, including p-n junction diodes, bipolar transistors, Schottky diodes, and insulated-gate field-effect transistors; electron emission; and superconductive devices.

### **ECE 307 - (4) (Y)**

#### **Electronics II**

*Prerequisite:* ECE 204

Construction of electronic circuit design to specifications. Focuses on computer simulation, construction, and testing of designed circuits in the laboratory to verify predicted performance. Includes differential amplifiers, feedback amplifiers, multivibrators, and digital circuits. Three lecture and three laboratory hours.

### **ECE 309 - (3) (Y)**

#### **Electromagnetic Fields**

*Prerequisite:* PHYS 241E, APMA 213, and ECE 203

Analyzes the basic laws of electromagnetic theory, beginning with static electric and magnetic fields, and concluding with dynamic E&M fields; plane wave propagation in various media; Maxwell's Laws in differential and integral form; electrical properties of matter; transmission lines, waveguides, and elementary antennas.

### **ECE 310 - (4) (Y)**

#### **Electromechanical Energy Conversion**

*Prerequisite:* ECE 203, PHYS 241E, and CS 101, or instructor permission

Analyzes the principles of electromechanical energy conversion; three-phase circuit analysis; magnetic circuits and nonlinearity; transformers; DC, synchronous, and induction machines; equivalent circuit models; power electronic control of machines. Laboratory, computer, and design exercises complement coverage of fundamental principles.

### **ECE 323 - (3) (Y)**

#### **Signals and Systems I**

*Prerequisite:* ECE 203 and APMA 213

Develops tools for analyzing signals and systems operating in continuous-time, with applications to control, communications, and signal processing. Primary concepts are representation of signals, linear time-invariant systems, Fourier analysis of signals, frequency response, and frequency-domain input/output analysis, the Laplace transform, and linear feedback principles. Practical examples are employed throughout, and regular usage of computer tools (Matlab, CC) is incorporated.

### **ECE 324 - (3) (Y)**

#### **Signals and Systems II**

*Prerequisite:* ECE 323

Sequel to ECE 323; provides analogous tools for analyzing discrete-time signals and systems, with applications to discrete-time signal processing and control. Sampling and reconstruction of continuous-time signals provides the transition between CT and DT settings. State space methods are also introduced.

### **ECE 333 - (3) (S)**

#### **Computer Architecture**

*Prerequisite:* CS 201 and ECE/CS 230 with grades of C- or higher

Includes the organization and architecture of computer systems hardware; instruction set architectures; addressing modes; register transfer notation; processor design and computer arithmetic; memory systems; hardware implementations of virtual memory, and input/output control and devices. Cross-listed as CS 333.

### **ECE 363 - (3) (S)**

#### **Digital Integrated Circuits**

*Prerequisite:* ECE/CS 230 and ECE 204

Digital CMOS circuits. MOSFET transistor. Combinational circuits. Sequential circuits. Design simple digital gates and circuits at the transistor level. Simulate designed circuits to verify performance. Three credit hours.

### **ECE 402 - (3) (Y)**

#### **Linear Control Systems**

*Prerequisite:* ECE 323 or instructor permission

Explores the modeling of linear dynamic systems via differential equations and transfer functions utilizing state space representations and classical input-output representations; the analysis of systems in the time and frequency domains; study of closed-loop systems; state-space methods and the classical stability tests, such as the Routh-Hurwitz criterion, Nyquist criterion, root-locus plots and Bode plots. Studies compensation design through lead and lag networks, rate feedback, and linear state-variable feedback.

### **ECE 403 - (1 1/2) (Y)**

#### **Control Laboratory**

*Corequisite:* ECE 402

A laboratory consisting of design, analysis, construction, and testing of electrical and electromechanical circuits and devices.

### **ECE 407, 408 - (1-3) (SI)**

#### **Electrical Engineering Projects**

*Prerequisite:* instructor permission

Under faculty supervision, students plan a project of at least one semester's duration, conduct the analysis or design and test, and report on the results. If this work is to be the basis for an undergraduate thesis, the course should be taken no later than the seventh semester.

### **ECE 409 - (3) (Y)**

#### **Electromagnetic Waves and Propagation**

*Prerequisite:* ECE 309

Analysis of the principles of electromagnetic propagation in bounded and unbounded media; transmission line theory, Smith Charts, and impedance matching; plane wave propagation in dielectric and conductive materials, reflection and transmission at interfaces; field analysis of waveguides, waveguides with cylindrical conducting boundaries, dielectric waveguides; electromagnetic radiation and the fundamental properties of antennas.

### **ECE 410 - (1 1/2) (Y)**

#### **Electromechanical Energy Conversion Laboratory**

*Prerequisite:* ECE 309 and 204; *corequisite:* ECE 310

Laboratory investigations of electromechanical energy conversion. Includes three-phase circuit analysis; magnetic coupling, magnetic forces, and nonlinearity; transformers; DC, synchronous and induction machines; equivalent circuit models; and power electronic control of machines.

### **ECE 411 - (3) (SI)**

#### **Bioelectricity**

*Prerequisite:* ECE 203, BIOM 301 or instructor permission

Studies the biophysical mechanisms governing production and transmission of bioelectric signals, measurement of these signals and their analysis in basic and clinical electrophysiology. Introduces the principles of design and operation of therapeutic medical devices used in the cardiovascular and nervous systems. Includes membrane potential, action potentials, channels and synaptic transmission, electrodes, electrocardiography, pacemakers, defibrillators, and neural assist devices. Cross-listed as BIOM 411.

### **ECE 412 - (3) (Y)**

#### **Digital Control Systems**

*Prerequisite:* ECE 324 and 402, or instructor permission

Analyzes the design of dynamic systems that contain digital computers; the Z transform; block diagrams and transfer functions in the z-domain; block diagrams, frequency response and stability in the z-domain; state space methods; and design using the z-transform and state methods.

### **ECE 415 - (1 1/2) (Y)**

#### **Microelectronic Integrated Circuit Fabrication Laboratory**

*Corequisite:* ECE 564

Fabrication and testing of MOS capacitors. Determination of material properties, including carrier concentration, mobility, lifetime, orientation, and layer thickness. Device fabrication using oxidation, diffusion, evaporation, and device testing of MOS and power bipolar transistors.

**ECE 420 - (3) (Y)****Communications**

*Prerequisite:* APMA 310, ECE 324

Explores the statistical methods of analyzing communications systems: random signals and noise, statistical communication theory, and digital communications. Analysis of baseband and carrier transmission techniques; and design examples in satellite communications.

**ECE 422 - (1 1/2) (Y)****Communication Systems Laboratory**

*Prerequisite:* ECE 324; *corequisite:* ECE 420

Provides first-hand exposure to communications practice, including response of systems, signal theory, modulation and detection, sampling and quantization, digital signal processing, and receiver design.

**ECE 434 - (3) (Y)****Fault-Tolerant Computing**

*Prerequisite:* ECE/CS 333, APMA 213 and 310 or equivalent, with grades of C- or higher, or instructor permission

Focuses on the techniques for designing and analyzing dependable computer-based systems. Topics include fault models and effects, fault avoidance techniques, hardware redundancy, error detecting and correcting codes, time redundancy, software redundancy, combinatorial reliability modeling, Markov reliability modeling, availability modeling, maintainability, safety modeling, trade-off analysis, design for testability, and the testing of redundant digital systems. Cross-listed as CS 434.

**ECE 435 - (4 1/2) (Y)****Computer Organization and Design**

*Prerequisite:* ECE 333 or instructor permission

Integration of computer organization concepts, such as data flow, instruction interpretation, memory systems, interfacing, and microprogramming with practical and systematic digital design methods such as behavioral versus structural descriptions, divide-and-conquer, hierarchical conceptual levels, trade-offs, iteration, and postponement of detail. Design exercises are accomplished using a hardware description language and simulation.

**ECE 436 - (4 1/2) (Y)****Advanced Digital Design**

*Prerequisite:* ECE 435 or instructor permission

Analyzes digital hardware and design; digital system organization; digital technologies; and testing. A semester-long hardware design project is conducted.

**ECE 457 - (3) (Y)****Computer Networks**

*Corequisite:* CS 333

A first course in communication networks for upper-level undergraduate students. Topics include the design of modern communication networks; point-to-point and broadcast

network solutions; advanced issues such as Gigabit networks; ATM networks; and real-time communications. Cross-listed as CS 457.

**ECE 473 - (3) (Y)****Analog Integrated Circuits**

*Prerequisite:* ECE 303 and 307

Topics include the design and analysis of analog integrated circuits; feedback amplifier analysis and design, including stability, compensation, and offset-correction; layout and floor-planning issues associated with mixed-signal IC design; selected applications of analog circuits such as A/D and D/A converters, references, and comparators; extensive use of CAD tools for design entry, simulation, and layout; and the creation of an analog integrated circuit design project.

**ECE 482 - (1 1/2) (Y)****Microwave Engineering Laboratory**

*Corequisite:* ECE 556 or instructor permission

Analyzes the measurement and behavior of high-frequency circuits and components; equivalent circuit models for lumped elements; measurement of standing waves, power, and frequency; use of vector network analyzers and spectrum analyzers; and computer-aided design, fabrication, and characterization of microstrip circuits.

**ECE 525 - (3) (SI)****Introduction to Robotics**

*Prerequisite:* ECE 402, or 621, or equivalent

Analyzes kinematics, dynamics and control of robot manipulators, and sensor and actuator technologies (including machine vision) relevant to robotics. Includes a robotics system design project in which students completely design a robotic system for a particular application and present it in class. Includes literature related to emerging technologies and Internet resources relevant to robotics.

**ECE 541 - (3) (Y)****Optics and Lasers**

*Prerequisite:* ECE 303, 309, and 323

Reviews the electromagnetic principles of optics: Maxwell's equations; reflection and transmission of electromagnetic fields at dielectric interfaces; Gaussian beams; interference and diffraction; laser theory with illustrations chosen from atomic, gas, and semiconductor laser systems; photomultipliers and semiconductor-based detectors; and noise theory and noise sources in optical detection.

**ECE 556 - (3) (Y)****Microwave Engineering I**

*Prerequisite:* ECE 309

Design and analysis of passive microwave circuits. Topics include transmission lines, electromagnetic field theory, waveguides, microwave network analysis and signal flow graphs, impedance matching and tuning,

resonators, power dividers and directional couplers, and microwave filters.

**ECE 563 - (3) (Y)****Introduction to VLSI**

*Prerequisite:* ECE 230 or CS 230; ECE 204 and 303

Analyzes NMOS and PMOS transistor design, CMOS fabrication, fabrication design rules, inverter design, cell design using computer aided design tool "Magic," chip layout and design, VLSI circuit design and implementation using the MOSIS process.

**ECE 564 - (3) (Y)****Microelectronic Integrated Circuit Fabrication**

*Prerequisite:* ECE 303 or equivalent

Analyzes fabrication technology and MOS device design for integrated circuits. Discusses crystal growth and characterization; oxide growth and deposition; diffusion; ion-implantation; metalization; etching and high resolution lithography; MOS capacitor and MOSFET device theory including equivalent circuit model derivation; and constraints presented by VLSI fabrication processes.

**ECE 576 - (3) (Y)****Digital Signal Processing**

*Prerequisite:* ECE 323 and 324 or equivalent

Fundamentals of discrete-time signal processing are presented. Topics include discrete-time linear systems, z-transforms, the DFT and FFT algorithms, digital filter design, and problem-solving using the computer.

**ECE 586/587 - (1-3) (SI)****Special Topics in Electrical Engineering**

*Prerequisite:* instructor permission

A first-level graduate/advanced undergraduate course covering a topic not normally covered in the course offerings. The topic usually reflects new developments in the electrical and computer engineering field. Offering is based on student and faculty interests.

**Engineering****(Interdepartmental)****ENGR 141R-142R - (3) (Y)****Synthesis Design I and II**

*Prerequisite:* first-year Rodman scholar status

Introduces engineering, emphasizing the creative aspects of the profession. Rudiments of design methodology utilizing a case study approach with individual and small team assignments/projects. Evolution of concepts to multi-objective design examples, decision-making and optimization; cases varying from small product design to large scale facilities with life-cycle impact. Instruction on estimations, sketching, computer graphics, economics, spreadsheet analysis, human factors, planning and scheduling, elementary

statistics, safety and risk analysis, materials and manufacturing, engineering ethics. Lectures followed by recitation or workshop sessions.

#### **ENGR 162 - (4) (Y)**

##### **Introduction to Engineering**

*Prerequisite:* enrollment in engineering or permission of course coordinator  
Integrates problem solving and design practice. Encourages the development of skills in using computer application packages for web page design, modeling and visualization (CAD), spreadsheets, and a math solver. Applies these skills to computer assignments and team design projects that feature conceptual design, analytical design, and design and build activities. Topics include methodologies for computation, problem solving, and design; graphing data; linear regression; plotting functions; matrix manipulation; modeling and visualization; and engineering optimization.

#### **ENGR 488 - (3) (Y)**

##### **Aspects of Engineering Practice**

This course will concentrate in examining and clarifying human values and practices in organizations. It is intended to complement the technical education programs offered by SEAS. The course will provide an introduction to a number of critical skills and competencies that will be very useful in the technical and business world. These include leadership, working in teams, management of organizations, conflict resolution, balancing career and personal needs and analyzing specific situations and exploring alternative outcomes.

#### **ENGR 489 - (0-3) (S)**

##### **Industrial Applications**

Students register for this course to complement an industry work experience. Topics focus on the application of engineering principles, analysis, methods and best practices in an industrial setting. A final report is required. Registration is only offered on a Credit/No Credit basis. Courses taken for Credit/No Credit may not be used for any major or degree requirements.

#### **ENGR 492 - (0) (Y)**

##### **Engineering License Review**

*Corequisite:* formal application for state registration

Overview of registration laws and procedures. Review of engineering fundamentals preparatory to public examination for the "Engineer in Training" part of the professional engineers examination. Three hours of lecture up to the licensing examination.

#### **ENGR 495/499 - (3) (Y)**

##### **Special Topics in Engineering**

*Prerequisite:* instructor permission

Advanced undergraduate courses on topics not covered in the course offerings and based on student and faculty interests.

## **Materials Science and Engineering**

#### **MSE 201 - (3) (S)**

##### **Materials That Shape Our Civilization**

A general review of structure, properties, methods of production, uses and world supply of the materials on which present and past civilizations have been based, including materials used in heavy industry, construction, communications, energy production, and medicine as well as textiles and naturally-occurring organic materials. Cross-listed as EVSC 201.

#### **MSE 209 - (3) (Y)**

##### **Introduction to the Science and Engineering of Materials**

The collective properties of the materials in an engineering structure often dictate the feasibility of the design. Provides the scientific foundation for understanding the relations between the properties, microstructure, and behavior during use of metals, polymers, and ceramics. Develops a vocabulary for the description of the empirical facts and theoretical ideas about the various levels of structure from atoms, through defects in crystals, to larger scale morphology of practical engineering materials.

#### **MSE 301 - (3) (Y)**

##### **Corrosion and its Prevention**

*Prerequisite:* MSE 209 or instructor permission

Includes basic electrochemical principles and terminology, definitions and magnitude of corrosion, thermodynamics and kinetics of corrosion, examples of corrosion, experimental techniques to measure and evaluate corrosion, corrosion prevention, passivation, stress corrosion cracking, and hydrogen embrittlement.

#### **MSE 301L - (1) (Y)**

##### **Corrosion Engineering Laboratory**

Provides instruction in standard corrosion experiments that demonstrate the instrumentation of corrosion testing and some of the accelerated forms of evaluating metals' susceptibility to various forms of corrosion attack. Standard experiments involving cathodic protection, anodic protection, and inhibitors. MSE 301 may be taken without the lab, but MSE 301L may not be taken without the lecture.

#### **MSE 304 - (3) (Y)**

##### **Structure and Properties of Polymeric Materials**

*Prerequisite:* MSE 209 or equivalent

Examines polymeric materials from their molecular structure and morphological organization to their macroscopic properties. Topics include polymerization reactions; molecular weight determination; solution behavior; organization of crystalline and amorphous polymers; rubber elasticity; crystallization

kinetics; morphology; mechanical, optical, and electrical properties; applications and materials selection; and degradation and recycling.

#### **MSE 304L - (1) (Y)**

##### **Structures and Properties Laboratory**

*Prerequisite:* MSE 209

Demonstrates the phenomena and experimental techniques used to establish the relationships between the structures and properties of metals and polymers. Experiments include viscometry, X-ray diffraction, light scattering, optical microscopy, hardness and impact tests, thermal analysis, and computer simulations.

#### **MSE 305 - (3) (Y)**

##### **Phase Diagrams and Kinetics of Materials**

*Prerequisite:* MAE 210 or CHE 202; APMA 213

Applies thermodynamic principles developed in MAE 210 or CHE 202 to material systems. Includes phase equilibria; phase diagrams and free energy curves; solution thermodynamics; and the kinetics of thermal and mass diffusion in binary, single- and two-phase solids.

#### **MSE 306 - (3) (Y)**

##### **Physical Metallurgy Principles: Structures and Properties of Metals**

*Corequisite:* MSE 304 or 306

Studies the fundamental concepts of physical metallurgy at an advanced undergraduate level. These include metallic bonding, crystallography of nanostructures, preferred orientation and texture, point defects, dislocations and deformation, grain boundary structure, solid state phase transformations, precipitation age hardening, and martensitic reactions, as well as hardenability and how each of these effects the strengthening mechanisms in metallic materials. Nano- and microstructures, composition and processing are linked to macroscopic properties. Introduces physical metallurgy characterization techniques, such as X-ray diffraction, stereographic projections, metallography, and electron microscopy methods.

#### **MSE 310 - (3) (Y)**

##### **Materials Science Laboratory**

*Prerequisite:* MSE 209 or instructor permission

Experimental study of the structure and properties of materials. Course amplifies topics covered in MSE 209 through experimentation and analysis. Experiment topics include atomic and microscopic structure, mechanical properties of metals, polymers and composites, electrical properties, and corrosion characteristics. Introduction to modern experimental methods and instruments used for materials characterization. Two lecture hours and three laboratory hours.

**MSE 451, 452 - (5) (Y)****Special Project in Materials Science and Engineering**

*Prerequisite:* professional standing and prior approval by a faculty member who is project supervisor

A project in the materials science field that requires individual laboratory investigation. Each student works on an individual project in the research area of a supervisor. The student is required to conduct a literature search and to become familiar with the necessary experimental techniques, such as electron microscopy, X-ray diffraction, and ultra-high vacuum techniques. A comprehensive report on the results of the experimental investigation and a final examination are required. One hour of conference, eight hours of laboratory per week.

**MSE 500 - (1-3) (ST)****Special Topics in Materials Science and Engineering**

*Prerequisite:* instructor permission

A first-level graduate/advanced undergraduate course covering a topic not normally covered in the course offerings. The topic usually reflects new developments in the materials science and engineering field. Offering is based on student and faculty interests.

**MSE 512 - (3) (Y)****Introduction to Biomaterials**

*Prerequisite:* MSE 209 and BIOM 301 or equivalent, or instructor permission

Provides a multi-disciplinary perspective on the phenomenon and processes that govern material-tissue interactions with the soft tissue, hard tissue, and cardiovascular environments. Emphasizes both sides of the biomaterials interface, so that events at the interface are examined and topics on material durability and tissue compatibility are discussed.

**MSE 524 - (3) (Y)****Modeling in Materials Science**

*Prerequisite:* at least two 300-400 level MSE courses or instructor permission

Introduces computer modeling in atomistics, kinetics and diffusion, elasticity, and processing. Analyzes the energy and configuration of defects in materials, such as solute segregation, phase transformations, stresses in multi-component systems, and microstructural development during processing.

**MSE 532 - (3) (Y)****Deformation and Fracture of Materials During Processing and Service**

*Prerequisite:* MSE 306 or instructor permission

Considers deformation and fracture through integration of materials science microstructure and solid mechanics principles, emphasizing the mechanical behavior of metallic alloys and engineering polymers. Metal deformation is understood based on elasticity theory and dislocation concepts. Fracture is understood based on continuum fracture

mechanics and microstructural damage mechanisms. Additional topics include fatigue loading, elevated temperature behavior, material embrittlement, time-dependency, experimental design, and life prediction.

**MSE 567 - (3) (Y)****Electronic, Optical and Magnetic Properties of Materials**

Explore the fundamental physical laws governing electrons in solids, and show how that knowledge can be applied to understanding electronic, optical and magnetic properties. Students will gain an understanding of how these properties vary between different types of materials, and thus why specific materials are optimal for important technological applications. It will also be shown how processing issues further define materials choices for specific applications.

**Mechanical and Aerospace Engineering****MAE 200 - (3) (Y)****Introduction to Mechanical Engineering**

*Prerequisite:* ENGR 162 and PHYS 142E

Overview of the mechanical engineer's role as analyst, designer, and manager. Introduction to manufacturing tools, equipment, and processes; properties of materials relative to manufacture and design; engineering design graphics with Autocad; blueprint reading, sectioning, auxiliary views; analysis and design of mechanical devices; engineering project management and control with computer aided project organization; applications of project management to plant layout and production lines; and plant tours to local industry. Labs include hands on experience with tools and materials, dissection of automobile transmissions and other devices. Two lectures, one laboratory period.

**MAE 201 - (3) (Y)****Introduction to Aerospace Engineering**

*Prerequisite:* enrollment in Engineering or permission of instructor

Historical introduction, standard atmosphere, basic aerodynamics, airfoils and wings, flight mechanics, stability and control, propulsion (airbreathing, rocket and space), orbital mechanics, space environment, advanced flight vehicles. Lectures followed by laboratory demonstrations.

**MAE 202 - (3) (Y)****Applications of Electronics**

*Prerequisite:* PHYS 241

Topics include the fundamentals of applied electronics and electrical principles; review of linear DC and AC circuits; nonlinear analog devices: diodes, operational amplifiers, and various IC devices; electromagnetic applications of relays, transformer, and motors; applications to instrumentation sensors, signal conditioning, and output devices; and introductory digital signal processing

principles. Laboratory provides hands-on exercises with motors, sensors, and circuit elements. Two lectures and one laboratory period.

**MAE 209 - (3) (Y)****Applied Probability and Statistics**

*Prerequisite:* APMA 212

Focuses on the application of probability and statistical analysis to engineering decision analysis. An applied course emphasizing data description, inference (confidence intervals and hypothesis tests), model building, designing engineering experiments, and statistical quality control. Statistical methods are presented within the context of real mechanical engineering programs. Includes readings, homework, team projects, reports, and in-class experiment design and data generation and analysis. Provides an active learning environment that fosters the development of skills required for solid engineering decisions. Cross-listed as CE 209.

**MAE 210 - (3) (S)****Thermodynamics**

*Prerequisite:* APMA 111

Includes the formulation of the first and second laws of thermodynamics; energy conservation; concepts of equilibrium, temperature, energy, and entropy; equations of state; processes involving energy transfer as work and heat; reversibility and irreversibility; closed and open systems; and cyclic processes. Three lecture and one laboratory/workshop hour per week. Cross-listed as CHE 202.

**MAE 231 - (4) (S)****Statics and Strength of Materials**

*Corequisite:* PHYS 142E

Analyzes the basic concepts of mechanics of deformable solids; systems of forces and couples; equilibrium of particles and rigid bodies; internal forces and analysis of structures: trusses, frames, machines, and beams; distributed forces; centroids and moments of inertia; and an introduction to stress, strain, constitutive relations, bending of beams, torsion, shearing, deflection of beams, column buckling, fatigue, and failure theory. Four lectures plus one workshop. Students may not earn credit for both MAE 231 and CE 206 or 207.

**MAE 232 - (3) (S)****Dynamics**

*Prerequisite:* PHYS 142E and MAE 231

Kinematic and kinetic aspects of motion modeling applied to rigid bodies and mechanisms. Focus on free-body-analysis. Use of work-energy and impulse-momentum motion prediction methods. Use of Cartesian and simple non-Cartesian coordinate systems. Rotational motion, angular momentum, and rotational kinetic-energy modeling; body mass rotational moment of inertia. Relative-velocity and relative-acceleration connection relations/methods, including use of moving Cartesian coordinate systems. Intro-

duction to 3d motion modeling. Computational applications, one hour workshop. Students may not earn credit for both MAE 232 and CE 206 or 207.

**MAE 263, 264 - (1½) (Y)**  
**Intermediate Design Topics in Aerospace Engineering**

*Prerequisite:* second-year standing  
 Application of basic engineering sciences, design methods, and systems analysis to ongoing design projects in aerospace engineering. Topic varies based on student and faculty interests and current upper-level design projects.

**MAE 301 - (3) (Y)**  
**Astronautics**

*Prerequisite:* MAE 232  
 Discussion of the Keplerian two-body problem; elliptic, parabolic, and hyperbolic orbits; solution of Kepler's equation and analogs; the classical orbital elements; orbit determination; prediction of future position and velocity; orbital perturbations; introduction to estimation theory; patched-conic analysis of interplanetary flight; Lambert's two-point boundary value problem; mission planning; chemical rocket propulsion; propellant requirements; staging; atmospheric reentry dynamics; the space environment; and an introduction to spacecraft attitude dynamics.

**MAE 312 - (3) (Y)**  
**Thermal Systems Analysis**

*Prerequisite:* MAE 210  
 Analyzes the thermodynamics of reactive and nonreactive, multi-component systems; energy cycles; and thermodynamic analysis of energy conversion systems.

**MAE 314 - (4) (Y)**  
**Elements of Heat and Mass Transfer**

*Prerequisite:* MAE 321 and CS 101  
 Analyzes steady state and transient heat conduction in solids with elementary analytical and numerical solution techniques; fundamentals of radiant heat transfer, including considerations for black, gray, and diffuse surfaces and the electrical analogy for systems having multiple surfaces; free and forced convective heat transfer with applications of boundary layer theory, Reynolds analogy, and dimensional analysis; and an introduction to mass transfer by diffusion using the heat-mass transfer analogy. Three lectures and one lab period.

**MAE 321 - (4) (Y)**  
**Fluid Mechanics**

*Prerequisite:* APMA 213 and MAE 210  
 Introduction to fluid flow concepts and equations; integral and differential forms of mass, momentum, and energy conservation with emphasis on one-dimensional flow; fluid statics; Bernoulli's equation; viscous effects; Couette flow, Poiseuille flow, and pipe flow; introduction to boundary layers; one-dimensional compressible flow; normal shock waves; flow with friction; flow

with heat addition; isothermal flow; and applications.

**MAE 322 - (3) (Y)**  
**Advanced Fluid Mechanics**

*Prerequisite:* MAE 321 or equivalent; APMA 314

Analyzes ideal fluids; velocity potential; stream function; complex potential; Blasius theorem; boundary conditions; superposition; circulation; vorticity; thin airfoil theory; two-dimensional gas dynamics; acoustic waves; normal and oblique shock waves; shock reflections; Prandtl-Meyer expansion; quasi one-dimensional compressible flow; converging-diverging nozzles; diffusers; choked flows; flow with friction; flow with heat addition; isothermal flow; linearized flows; Prandtl-Glauert correction; and applications.

**MAE 331 - (3) (Y)**  
**Aerospace Structures**

*Prerequisite:* MAE 231  
 Analyzes the design of elements under combined stresses; bending and torsional stresses in thin-walled beams; energy and other methods applied to statically determinate and indeterminate aerospace structural elements; buckling of simple structural members; and matrix and finite element analysis.

**MAE 340 - (3) (SI)**  
**Applied Computer Graphics**

*Prerequisite:* CS 101  
 Studies graphics fundamentals, including two- and three-dimensional coordinate geometry and matrix transformations used for viewing; visual realism and rendering; curves and surfaces; and engineering data visualization techniques. Most assignments are implemented in a high-level programming language.

**MAE 342 - (3) (Y)**  
**Computational Methods in Aerospace Engineering**

*Prerequisite:* APMA 314 and MAE 321  
 Introduces solid modeling software with applications to aircraft and spacecraft; solutions of the flow over aerodynamically shaped bodies using panel method codes and Navier Stokes codes; computation and analysis of aerodynamic quantities, such as lift, drag, and moments; and numerical methods for analyzing dynamics of spacecraft.

**MAE 352 - (3) (Y)**  
**Engineering Materials: Properties and Applications**

*Prerequisite:* CHEM 151; *corequisite:* MAE 231  
 Introduces physical-chemical/microstructural and working mechanical properties, along with practical applications, for materials of wide interest in engineering design. Includes common metal, polymer, ceramic, and composite materials. Topics include

standard materials names/designations; standard forming methods; usual strengthening means; temperature and temperature-history effects; common processing methods; common properties measurement and other testing methods; oxidation/corrosion processes; sources of abrupt failure; creep; and viscoelastic behaviors. Case-studies illustrate engineering application advantages and disadvantages for specific materials, forming, and processing methods. Use of material property data base.

**MAE 362 - (4) (Y)**  
**Machine Elements and Fatigue in Design**

*Prerequisite:* MAE 200 and 231  
 Applies mechanical analysis to the basic design of machine elements; basic concepts in statistics and reliability analysis, advanced strength of materials, and fatigue analysis; and the practical design and applications of materials to fastening systems, power screws, springs, bearings, gears, brake clutches and flexible power transmission elements. Introduction to the finite element method. Three lectures and one laboratory period.

**MAE 363, 364 - (1½) (Y)**  
**Intermediate Design Topics in Aerospace Engineering**

*Prerequisite:* third-year standing  
 Applies basic engineering sciences, design methods, and systems analysis to ongoing design projects in aerospace engineering. Topics vary based on student and faculty interests and current upper-level design projects.

**MAE 371 - (3) (Y)**  
**Mechanical Systems Modeling**

*Prerequisite:* MAE 232 and APMA 213  
 Topics include the analysis of linear, mechanical, fluid, thermal and chemical systems, including first and second order systems, Laplace Transforms, block diagrams, Bode plots, stability, and applications.

**MAE 373 - (3) (Y)**  
**Flight Vehicle Dynamics**

*Prerequisite:* MAE 201 and 232  
 Introduces definitions and concepts and includes a review of longitudinal static stability; rigid body dynamics: general equations of motion, rotating coordinate systems; small disturbance theory; atmospheric flight mechanics, stability derivatives; motion analysis of aircraft; static and dynamic stability; aircraft handling qualities; and an introduction to flight control systems and automatic stabilization.

**MAE 381 - (2) (Y)**  
**Experimental Methods Laboratory**

*Prerequisite:* PHYS 241E and MAE 210; *corequisite:* MAE 231 and 321  
 Includes basic concepts and methods in engineering measurements including systems, quantities, units, techniques, statistics, and uncertainties; and practical applications in

the fields of fluid and solid mechanics, thermodynamics, heat transfer, electrical circuitry, and mechanical devices. Develops skills in experimentation and familiarity with instruments. One lecture and three laboratory hours, plus preparation of reports.

**MAE 382 - (3) (Y)**

**Aerodynamics Laboratory**

*Prerequisite:* MAE 201, 321 and 381; *corequisite:* MAE 322

Investigates low-speed nozzle and jet flows, wing aerodynamic behaviors in a small low-speed wind tunnel, and aerodynamic model testing in a larger low-speed wind tunnel. Building, testing, and trajectory-tracking for small rockets; trajectory predictions. Examines supersonic flow and aerodynamic behaviors in a small supersonic wind tunnel.

**MAE 400 - (3) (Y)**

**Financial Aspects of Engineering**

Includes the general principles of taxation: calculation of income taxes; economic considerations in practical engineering problems and in business decisions; costs, interest, depreciation, amortization, present worth, rate of return on investments; and some facets of initiating small businesses. Focuses on the significance of compounded interest to long-term financial projects.

**MAE 411 - (3) (Y)**

**Thermal Environment Engineering**

*Prerequisite:* MAE 321

Analysis and synthesis of systems to produce control of the thermal environment. Emphasizes the use of design for optimum control of climate within enclosures for human occupancy, processes, or special equipment.

**MAE 412 - (3) (Y)**

**Air Breathing Propulsion**

*Prerequisite:* MAE 321

Reviews mechanics and thermodynamics of compressible fluids and includes an analysis of the basic mechanisms for thrust generation in aerospace propulsion systems; the steady one-dimensional flow approximation; performance and cycle analysis of air-breathing engines, emphasizing jet engines (turbojet, turbofan, turboprop) and ramjets; aerothermodynamics of inlets, diffusers, combustors, and nozzles; performance of turbo-machinery; axial-flow and centrifugal compressors; turbines; and the matching of engine components.

**MAE 413 - (3) (O)**

**Rocket Propulsion**

*Prerequisite:* CHEM 151, MAE 210, 232, 301 and 321; *corequisite:* MAE 322 and 342

Introduces rocket-engine fundamentals, science, engineering, and technology. Includes design and optimization problems; materials, temperature-exposure, and stress-strain issues; connecting-interest rocket flight mechanics and trajectories; rocket staging issues; liquid propellants; liquid-propellant

engine designs; solid propellants; solid-propellant engine designs; rocket thrust-chamber flow behaviors and modelings; the EDDYBL computer boundary-layer modeling code (including convective heat transfer modeling); modeling of liquid-propellant combustion processes; the STANJAN computer code; rocket exhaust jet/plume general behaviors; modeling methods; maneuver, orbit-adjustment, and attitude-adjustment engines; and specialty engines.

**MAE 414 - (3) (SI)**

**Principles of Air Pollution**

*Prerequisite:* MAE 312, 321, CHE 314 or 315  
Studies gaseous and particulate air pollutants and their effects on visibility, animate, and inanimate receptors; source emissions and principles of control; meteorological factors governing distribution and removal of air pollutants; air quality measurements; legal aspects of air pollution; and noise pollution.

**MAE 452 - (3) (Y)**

**Manufacturing and Process Technology**

*Prerequisite:* MAE 352

Includes familiarization with concepts of mass production tooling and automation; metallurgical and mechanical aspects of machining and metal forming; and experiments with machine tools. Two lecture and three laboratory hours.

**MAE 454 - (3) (Y)**

**Introduction to Composite Mechanics**

*Prerequisite:* MAE 231 or equivalent

Introduces engineering properties and advantages of advanced fibrous composites. Includes anisotropic, thermo-mechanical constitutive theory for plane-stress analysis; thermal-mechanical stress analysis of laminates subjected to inplane and bending loads; engineering properties of laminates; test methods and material response (in the lab); designing with composites; and computer implementation. Cross-listed as CE 455.

**MAE 461 - (3) (Y)**

**Machine Design I**

*Prerequisite:* MAE 362

Studies design process and project management, including case histories; manufacturing issues related to design; lubrication and hydrodynamic bearings; dynamic finite element analysis; and application to design for vibration suppression. Individual and team projects. Two lecture and two laboratory hours per week.

**MAE 462 - (3) (Y)**

**Machine Design II**

*Prerequisite:* MAE 362 or instructor permission

A continuation of MAE 461 that applies the design process to projects. Organization of design teams to work on specific semester-long design projects, including oral presenta-

tions and written reports. Two lecture and two laboratory hours per week.

**MAE 463 - (3) (Y)**

**Energy Systems Design I**

*Prerequisite:* MAE 312 and 314

Design of systems for the useful conversion of energy. Applications include various combustion systems that generate electricity and the control of air pollutant emissions from combustion systems. Considers the control and performance features present in such operating systems, as well as the economic optimization of capital and operating expense.

**MAE 464 - (3) (Y)**

**Energy Systems Design II**

*Prerequisite:* MAE 463 and 314

Design of systems for useful conversion of energy. Includes building air conditioning systems, heat exchangers, and energy storage systems. Considers the control and performance features present in such operating systems, as well as the economic optimization of capital and operating expense.

**MAE 465 - (3) (Y)**

**Aerospace Design I**

*Prerequisite:* MAE 201, 321, 322, 331, 342, 352, 373, or instructor permission; *corequisite:* MAE 412

Analyze design requirements for and produce conceptual design of an aircraft. Includes synthesis of aeronautics, aerospace materials, structures, propulsion, flight mechanics, stability and control, interior and external configuration, cockpit design and all systems. Work in teams to expose students to group dynamics, scheduling, and interdisciplinary activities. Trade studies and optimization. State-of-the-art report, presentations and interim report.

**MAE 466 - (3) (Y)**

**Aerospace Design II**

*Prerequisite:* MAE 465

A continuation of MAE 465. Completion of preliminary aircraft design, with cost analysis and manufacturability considerations. Submission of final report.

**MAE 471 - (4) (Y)**

**Mechatronics**

*Prerequisite:* MAE 202, 232, 381

Design of systems integrating mechanical components with electrical components and, generally, some form of computer control. Surveys electromechanical actuators, sensors, digital to analog conversion, and methods of computer control, including feedback and inverse kinematic trajectory planning. Includes individual and team design and testing projects involving physical hardware. Three lecture and two laboratory hours.

**MAE 473 - (3) (Y)**

**Introduction to Automatic Controls**

*Prerequisite:* MAE 232 and 371, or instructor permission

Discusses the mathematics of feedback con-

trol systems; transfer functions; basic servo theory; stability analysis; root locus techniques; and graphical methods. Applications to analysis and design of mechanical systems, emphasizing hydraulic, pneumatic, and electromechanical devices.

### **MAE 474 - (3) (SI)**

#### **Mechanical Vibrations**

*Prerequisite:* MAE 232

Studies free and forced vibration of damped and undamped single and multiple degree of freedom systems. Includes modeling of discrete and continuous mass systems; application to vibration measurement instruments; analysis of concepts of modal analysis; concepts of linear stability; application to rotating machinery, including the design of bearings and supports; discussion of static and dynamic balancing; influence coefficients; and least squares method.

### **MAE 491, 492 - (3) (SI)**

#### **Special Topics in Mechanical Engineering**

*Prerequisite:* fourth-year standing and instructor permission

Applies basic engineering science, design methods, and systems analysis to developing areas and current problems in mechanical engineering. Topics vary based on student and faculty interest.

### **MAE 493, 494 - (3) (SI)**

#### **Special Topics in Aerospace Engineering**

*Prerequisite:* fourth-year standing or instructor permission

Applies basic engineering science, design methods, and systems analysis to developing areas and current problems in aerospace engineering. Topics vary based on student and faculty interest.

### **MAE 495, 496 - (1 1/2) (Y)**

#### **Mechanical Engineering Special Project**

*Prerequisite:* professional standing and prior approval by a faculty member who is project supervisor

Individual survey, analysis, or apparatus project in the mechanical engineering field, concluded with the submission of a formal report. Subject originates with students wishing to develop a technical idea of personal interest. One hour conference per week.

### **MAE 497, 498 - (1 1/2) (Y)**

#### **Aerospace Engineering Special Projects**

*Prerequisite:* fourth year standing and consent of a department faculty member to serve as technical advisor

Applied research on a year-long basis in areas pertinent to aerospace engineering; conducted in close consultation with a departmental faculty advisor. Includes the design and construction of experiments, computational analysis, or the investigation of physical phenomena. The research may be related to ongoing faculty research and may be the topic of the senior thesis, but its scope must be significantly beyond that required for the thesis.

## **Physics**

### **PHYS 142E - (3) (Y-SS)**

#### **General Physics I**

*Prerequisite:* APMA 109; *corequisite:* PHYS 142W.

Analyzes classical mechanics, including vector algebra, particle kinematics and dynamics, energy and momentum, conservation laws, rotational dynamics, oscillatory motion, gravitation, thermodynamics, and kinetic theory of gases. Three lecture hours.

### **PHYS 142R - (3) (Y)**

#### **General Physics I**

*Prerequisite:* Rodman scholar status

Covers the same material as PHYS 142E, with certain topics treated in greater depth.

### **PHYS 142W - (1) (Y-SS)**

#### **General Physics I Workshop**

*Corequisite:* PHYS 142E

A required two-hour workshop accompanying PHYS 142E, including laboratory and tutorial activities.

### **PHYS 241E - (3) (Y)**

#### **General Physics II**

*Prerequisite:* PHYS 142E and APMA 111

Analyzes electrostatics, including conductors and insulators; DC circuits; magnetic forces and fields; magnetic effects of moving charges and currents; electromagnetic induction; Maxwell's equations; electromagnetic oscillations and waves. Introduces geometrical and physical optics. Three lecture hours; one hour recitation.

### **PHYS 241L - (1) (Y)**

#### **General Physics Laboratory**

*Corequisite:* PHYS 241E

Laboratory exercises in classical physics. Two hours laboratory.

## **Systems and Information Engineering**

### **SYS 201 - (3) (Y)**

#### **Systems Engineering Concepts**

*Prerequisite:* APMA 111 and 212

Introduces the concepts and process of systems engineering, emphasizing their use in the planning, design, construction, operation, maintenance, and overall management of the life-cycle of engineering and non-technological systems. Emphasizes teamwork in engineering problem solving, and includes case studies of real-world problems. Analyzes specifications and the process of evaluating alternatives and implementing results. Studies the dynamic interactions between technological, socioeconomic, and organizational elements of these processes through quantitative modeling, including topics from linear, non-linear, dynamic, discrete, continuous, and probabilistic modeling.

### **SYS 202 - (3) (Y)**

#### **Data and Information Engineering**

*Prerequisite:* CS 101, 201, and second-year standing in systems engineering

Introduces the integration and acquisition of information for decision-making using information technology. Discusses the impact of rapid software and hardware development on information integration, including the essential methodologies of client server and database systems. Topics include client server technology, industry standards, and development issues; the design and analysis of database systems, such as relational and object-oriented, exposure to a commercial database system, and the fourth-generation language SQL. Emphasizes application of these technologies through the analysis of different systems and the implementation of a database system.

### **SYS 204 - (3) (Y)**

#### **Data Management and Information Management**

*Prerequisite:* CS 110 or ENGR 162, or instructor permission

Students may not receive credit for both SYS 202 and SYS 204.

Introduces the integration and acquisition of information for decision-making using information technology. Discusses the impact of rapid software and hardware development on information integration, including the essential methodologies of client server and database systems. Topics include client server technology, the design and analysis of relational database systems, exposure to Microsoft Access, and the fourth-generation language SQL.

### **SYS 256 - (3) (Y)**

#### **Management of E-Commerce Systems**

*Prerequisite:* CS 110 or ENGR 162, or instructor permission

An introduction to the management and performance assessment of electronic commerce systems. Details of specific e-commerce technologies will be covered as background. Topics include: technologies, architectures, and infrastructures; supply-chain management; requirements definition and analysis; development lifecycles; customer behaviors; performance models; service metrics; waiting and response times; traffic characteristics; load forecasts and scenarios; resources and costs estimation; risk analysis; optimization; capacity planning; web authoring tools; programming languages; operating systems and hardware; prototyping and benchmarking; and deployment case studies.

### **SYS 321 - (3) (Y)**

#### **Network Modeling and Design**

*Prerequisite:* SYS 201

Introduction to optimization models involving network structure: theory, algorithms, and applications. We start by analyzing shortest path problems and work our way toward network models with less special structure, including general linear programs and multicommodity flows. Applications include (1) telecommunications network planning and design, (2) design and utiliza-

tion of transportation and distribution networks, and (3) project management and scheduling.

### **SYS 323 - (3) (Y)**

#### **Human Machine Interface**

*Prerequisite:* SYS 201 and third-year standing in systems engineering  
Approaches the human-computer interaction as an activity of the human whose productivity is increased by the use of the computer as a tool. Examines human physiology and psychology, considers the structure and operation of the computer, and models the interaction between the two using several methods. Evaluates usability and examines group work with networked computers. Includes group projects.

### **SYS 334 - (3) (Y)**

#### **System Evaluation**

*Prerequisite:* SYS 201, 321, and third-year standing in systems engineering  
Focuses on the evaluation of candidate system designs, design performance measures, and high-level trade studies of systems architectures. Includes identification of system goals; requirements and performance measures, including cost and non-technical requirements; design of experiments for performance evaluation; techniques of decision analysis for trade-studies (ranking of alternatives); presentation of system evaluations; and generation of a business case for presenting analysis results. Illustrates the concepts and processes of systems evaluations using case studies.

### **SYS 355 - (1) (Y)**

#### **Systems Engineering Design Colloquium I**

*Prerequisite:* third-year standing in systems engineering  
Students learn about the practice of systems engineering directly from practicing systems engineers. A variety of topics are covered by invited speakers from industry, government, and the academy (many of whom are alumni of our undergraduate program). Discussions include real engineering design projects, alternative career paths, graduate studies, professional development and advancement strategies, and more immediate options and opportunities for summer internships and capstone projects.

### **SYS 360 - (3) (Y)**

#### **Probability Models in Business Analysis and Economic Systems**

*Prerequisite:* SYS 201  
Introduction to stochastic models, with emphasis on applications to service and production operations and business systems. Topics include discrete time and continuous time Markov processes, elementary queuing systems, inventory theory, and reliability.

### **SYS 362 - (4) (Y)**

#### **Discrete Event Simulation**

*Prerequisite:* CS 201, APMA 310, 312, and third-year standing in systems engineering

Topics include the theory and practice of discrete-event simulation modeling and analysis; Monte Carlo methods, generating random numbers and variates, sampling distributions, and spreadsheet applications; discrete-event dynamic systems (DEDS), simulation logic and data structures, computational issues, experiment design, output analysis, model verification and validation, and case studies; and modern simulation languages, including animation. One-hour laboratory and design project.

### **SYS 421 - (4) (Y)**

#### **Data Analysis**

*Prerequisite:* SYS 202 and 360, APMA 312, and major in systems engineering  
Demonstrates how to design, build, and integrate a suite of information delivery and decision support tools that allow enterprises to transform the wide variety of data within their organizations into information to support successful decision making. Includes the use of regression models in understanding, prediction, and estimation; multidimensional databases and on-line analytical processing systems; the theory and practice of model construction using real data; and problem solving.

### **SYS 453 - (3) (S)**

#### **Systems Design I**

*Prerequisite:* SYS 321, 360, and major in systems engineering  
A design project extending throughout the fall semester. Involves the study of an actual open-ended situation, including problem formulation, data collection, analysis and interpretation, model building for the purpose of evaluating design options, model analysis, and generation of solutions. Includes an appropriate computer laboratory experience.

### **SYS 454 - (3) (S)**

#### **Systems Design II**

*Prerequisite:* SYS 453  
A design project extending throughout the spring semester. Involves the study of an actual open-ended situation, including problem formulation, data collection, analysis and interpretation, model building for the purpose of evaluating design options, model analysis, and generation of solutions. Includes an appropriate computer laboratory experience.

### **SYS 455 - (1) (Y)**

#### **Systems Engineering Design Colloquium II**

*Prerequisite:* Fourth-year standing in systems engineering  
A continuation of the third-year design colloquium; allows fourth-year students to learn about systems engineering directly from practicing systems engineers. Invited speakers discuss real engineering design projects, alternative career paths, graduate studies, professional development, and advancement strategies. Emphasizes recruiting practices and procedures and job

selection perspectives

### **SYS 481 - (3) (IR)**

**Selected Topics in Systems Engineering**  
*Prerequisite:* as specified for each offering.  
Detailed study of a selected topic determined by the current interest of faculty and students. Offered as required.

## **Technology, Culture, and Communication**

### **TCC 101 - (3) (Y)**

#### **Language Communication and the Technological Society**

Introduces the uses of language (technical, persuasive, and expressive) stressing its relevance to professionalism in engineering and applied science. Student participation in the Research Interview Project serves as the context for writing memoranda, abstracts, and technical proposals, and preparing oral presentations of technical material for a variety of audiences. Frequent short written and oral presentations are based on readings in a variety of modes of communication.

### **TCC 200 - (3) (IR)**

#### **Topics in Technology and Society**

Relates technology or engineering to the broader culture. The specific subject will differ from time to time.

### **TCC 201 - (3) (IR)**

#### **Thomas Jefferson's Interests in Science and Technology**

*Prerequisite:* TCC 101 or instructor permission  
Introduces Jefferson's use of scientific thinking in his major accomplishments and efforts to influence public policy, agriculture, education, invention, architecture, and religion. Readings in his writings, class discussions, guest lectures and field visits to local centers of Jefferson research. Short papers, in-class presentations, and a research paper is required.

### **TCC 203 - (3) (Y)**

#### **Man and Machine: Visions of Tyranny and Freedom in 19th- and 20th-Century Literature**

*Prerequisite:* TCC 101  
Analysis of attitudes toward the problem of the machine and technological advances in modern civilization, as reflected in selected American and European writings and films. Discussions, oral presentations, papers, and a final exam.

### **TCC 204 - (3) (Y)**

#### **Technology, Aggression, and Peace**

*Prerequisite:* TCC 101  
A study of the human potential for aggression and the relationship of technology to this potential. Students read and discuss a variety of theories about human behavior and the destructive impulse in humankind. Short essays, a research paper, group projects, and oral presentations enable students

to build and practice communications skills.

**TCC 206 - (3) (IR)**

**American Environmental History**

*Prerequisite:* TCC 101, ENWR 110, or equivalent

Explores the historical relationship between people and the environment in North America, from colonial times to the present. Topics include the role of culture, economics, politics, and technology in that relationship.

**TCC 207 - (3) (Y)**

**Utopias and the Technological Society**

*Prerequisite:* TCC 101

Lectures, readings, and discussions compare earlier and modern designs of the ideal society, stressing the relationship of their basic technologies to historical reality. Such writers as Plato, Thomas More, and Aldous Huxley are considered. Students give oral presentations, write short papers, and design a personal utopia.

**TCC 208 - (3) (IR)**

**History of Flight**

*Prerequisite:* TCC 101

Explores the development of flight from the earliest historical records of peoples' interest in flying through the achievements of the space age. Emphasizes the social and cultural impacts of flight, advances in technology, and the significance of the contribution of individuals. Guest lectures, film showings, visits to aviation museums, and student reports and projects supplement regular classroom lecture and discussion.

**TCC 209 - (3) (IR)**

**The History of Space Flight**

*Prerequisite:* TCC 101

Explores the history of space flight, from peoples' earliest interest in rockets through the most recent developments in aerospace technology. Examines the contributions of various scientists, engineers, and inventors to space travel; the major eras of aerospace history and the impacts of U.S. and international space programs on society.

**TCC 210 - (3) (Y)**

**Technology and Social Change in 19th-Century America**

*Prerequisite:* TCC 101

A study of the impacts of nineteenth-century American industrial development on the community, the worker, and engineering. Students make oral and written presentations, write short papers, and a research paper.

**TCC 211 - (3) (IR)**

**Values of Professionals**

*Prerequisite:* TCC 101

Examines the ways technical and non-technical professionals attribute worth to an idea, action, or object. Develops the student's abilities to discern, in the values typical of specific occupations, elements of the job (monetary gain), the calling (service and self-fulfillment), and the profession (conformity to

"guild" standards). Representative literature is read and discussed; each student is expected to speak and write articulately about values issues and to conduct elementary research in the topic.

**TCC 212 - (3) (IR)**

**Religion and Technology**

*Prerequisite:* TCC 101

A historical examination of the role of religion in the early development of technology; technology as a secular substitute for religion; and religious critiques of contemporary technological society. Equal time is spent on lectures, student-led discussions of the readings, and student oral presentations. Short papers and a major research project on a particular denomination's or congregation's attitudes toward technology-related issues.

**TCC 213 - (3) (IR)**

**American Technological and Industrial History in the Twentieth Century**

*Prerequisite:* TCC 101

Surveys the technological, business, and economic history of the U. S. from the 1860s to the 1980s. Focuses on key industries (railroads, autos, computers), corporate structures and functions, government intervention in the economy, and popular attitudes toward technological change.

**TCC 300 - (3) (IR)**

**Advanced Topics in Technology and Culture**

*Prerequisite:* TCC 101 and six credits of general education electives

Specific topics vary. Fulfills TCC 2\_\_ writing and speaking requirements.

**TCC 301 - (1) (S)**

**Topics in Science, Technology, and Culture**

Supplements existing undergraduate courses with additional research assignments. Generally taken by students wishing to fulfill the requirements for the minor in the history of science and technology.

**TCC 303 - (3) (SI)**

**The Presentation of Technical Information**

*Prerequisite:* TCC 101 or ENWR 110 or instructor permission

The principles of adapting scientific and technical information for communication in various media and for a variety of audiences and purposes.

**TCC 305 - (3) (SI)**

**Readings in the Literature of Science and Technology**

*Prerequisite:* TCC 101 or ENWR 110 or instructor permission

Readings in scientific and philosophical texts and discussions of the nature of scientific and technological thought. Students conduct panel discussions on new technologies and their intellectual and social impacts.

**TCC 311 - (3) (SI)**

**Readings in the History of Science and Technology**

*Prerequisite:* TCC 101 or ENWR 110 or instructor permission

Readings and discussion of selected works in the classic writings of engineers and scientists from the earliest records to the Renaissance.

**TCC 312 - (3) (IR)**

**History of Technology and Invention**

*Prerequisite:* TCC 101 or ENWR 110 or instructor permission

Surveys advances of technological knowledge through the ages. Includes the achievements of Egypt, Greece, and Rome; the beginnings of the concept of a labor-saving device in the middle ages; the technological background of the Industrial Revolution; the recent role of technology in shaping modern society.

**TCC 313 - (3) (Y)**

**Scientific and Technological Thinking**

*Prerequisite:* TCC 101 or ENWR 110 or instructor permission

Explores the ways scientists and inventors think, using concepts, theories, and methods borrowed from several disciplines, but focusing especially on psychology. Topics include experimental simulations of scientific reasoning, a cognitive framework for understanding creativity, and modeling discovery on a computer. Students read and discuss articles and conduct a short research project. Fulfills TCC 200-level writing and speaking requirements.

**TCC 315 - (3) (Y)**

**Invention and Design**

*Prerequisite:* TCC 101 or ENWR 110 or instructor permission

Investigates the way technology is created and improved. Offers a collaborative learning environment in which multi-disciplinary teams invent and design several modules that emulate problems, such as the invention of the telephone or the design of an expert system. Includes readings from psychology, history, computing, ethics, and engineering. Students keep design notebooks, present team project results, and write an integrative paper. Fulfills TCC 200-level writing and speaking requirements. Cross-listed as PSYC 419.

**TCC 395 - (1-3) (SI)**

**Independent Study: Technology in Culture**

*Prerequisite:* TCC 101, a 200-level TCC course, and instructor permission

Special tutorial with a topic declared in advance. Limited to undergraduate SEAS students with third- or fourth-year standing. Not to substitute for TCC 401, TCC 402. The topic, work plan, and conditions are arranged by contract between instructor and student and approved by the division chair, with a copy to be filed in the division office.

**TCC 401 - (3) (S, SS)****Western Technology and Culture**

*Prerequisite:* a 200-level TCC course or instructor permission

A historical perspective is presented in readings, films, and discussions, on Western civilization's views of technology. The undergraduate thesis project, which is initiated in this course, emphasizes oral and written communications at a professional level, and the role of social constraints and ethical obligations in engineering practice.

**TCC 402 - (3) (S, SS)****The Engineer, Ethics, and Society**

*Prerequisite:* TCC 401

Readings on, and discussions of, various kinds of valuing (social, institutional, scientific, intellectual, and personal) characteristic of professional work in engineering and applied science in modern technological society. Students complete the thesis project technical report. Continued consideration of indirect and unintended impacts of new technology and of health and safety issues.

**TCC 403 - (1) (SS)****Research Proposal Writing**

A course in technical and scientific communication for students entering the accelerated Bachelor's-Master's Degree Program. Offered in the summer session between the sixth and seventh semesters. Part of the required undergraduate humanities sequence for students in the accelerated program.

**TCC 501 - (3) (Y)****Perceptions of Technology in the Western World**

*Prerequisite:* students in the accelerated Bachelor's/Master's Program

Fall semester. May be taken in either the fourth or fifth year of the student's program. Seminars exploring the role of technology in the western world, based on assigned readings in the history, philosophy, or culture of technology.

**TCC 502 - (2) (Y)****Thesis and Research Presentation**

*Prerequisite:* students in the tenth semester of the accelerated Bachelor's/Master's Program

Spring semester. Seminars, lectures, and discussions related to research writing, leading to completion of the master's thesis (or project in departments not requiring a thesis). Topics include organization and style in the thesis writing with attention to logical, rhetorical, and ethical issues in science and engineering research writing.

**TCC 600 - (3) (Y)****Effective Technical Communication**

*Prerequisite:* graduate student status; instructor permission

Study and practice in effective presentation

of technical information in both written and oral form. Organizing for small- and large-scale presentations: summaries, proposals, scientific and technical reports, theses and dissertations, and articles for publication. Review of conventions of technical style and essentials of grammar and syntax. Assignments to be drawn from the student's thesis or other research where possible. Course does not offer instruction in remedial English or English as a second language.

**Technology Management and Policy****TMP 351 - (3) (Y)****The Technology and Product-Development Life Cycle**

*Prerequisite:* third-year standing or instructor permission.

Views technology, technology management, and product and process development from within a corporation. Emphasizes how firms manage or make decisions about technology and product development investments (research and development, project selection, product choices, process choices and improvement, new market introduction, product discontinuance or replacement). Course is built around a life cycle construct.

**TMP 352 - (3) (Y)****Science and Technology Public Policy**

Examines the "macro" aspects of science and technology management, namely the development of public policies aimed at promoting and regulating science and technology. Topics include the justifications for the federal government's efforts to promote or regulate science and technology; the historical evolution of the federal government's involvement in science policy; the players, organizations, and agencies who make science policy in the federal government; the reasons the government funds the research it does; how science and technology is regulated by the government; and, the roles state and local governments play in the development of local science and technology policies. Explores how science and technology policies are developed in response to challenges posed by the world economy, and how other countries manage their science and technology policies.

**TMP 399 - (3) (SI)****Case Studies in Technology Management and Policy**

A special topics course examining the interaction of technology, management, and policy issues in a specific context. The course could be organized around a technology, a company, an industrial or governmental sector, a piece of legislation, a court decision, a social issue, a time-period, a political entity, or some combination of these.