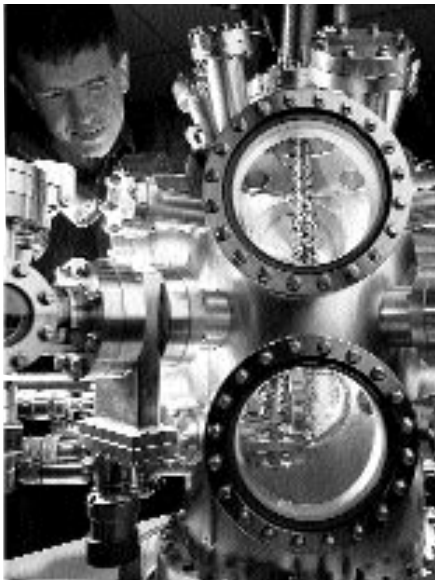
USC School of Engineering



The 2001 America's Best Graduate Schools' issue of U.S. News and World Report *ranks the USC School of Engineering 12th among the top graduate schools of engineering. Graduate students like Ildar Mukhametzhanov use state-of-the-art equipment, such as the Ultra-High Vacuum (UVH) Scanning Tunneling Microscope, to conduct research under the guidance of renowned faculty.*

Courses in engineering were first offered in 1906 in the basement of one of the oldest buildings on campus. Today, 150 full-time faculty serve about 1,700 undergraduates and 2,300 graduate students, utilizing state-of-the-art laboratories, classrooms, live interactive broadcast systems and the World Wide Web. The USC School of Engineering's research program of over $100 million per year is funded through strong ties with government and industry.

The goals of the School of Engineering are: to provide undergraduate and graduate programs of instruction for qualified students leading to academic degrees in engineering; to extend the frontiers of engineering knowledge by encouraging and assisting faculty in the pursuit and publication of research; to stimulate and encourage in its students those qualities of scholarship, leadership, and character that mark the true academic and professional engineer; to serve California and the nation in providing for the continuing education of engineering and scientific personnel; and to provide professional engineering leadership in the solution of community, regional, national and global problems.

The School of Engineering offers various programs leading to the Bachelor of Science, Master of Science and Engineer degrees; and, through the USC Graduate School, the Doctor of Philosophy degree.

Degrees and Requirements

The School of Engineering offers the following undergraduate curricula leading to the Bachelor of Science in: Aerospace Engineering, Aerospace Engineering (Astronautics), Applied Mechanics, Biomedical Engineering, Biomedical/Electrical Engineering (combined major), Biomedical/Mechanical Engineering (combined major), Biomedical Engineering (Biochemical Engineering), Chemical Engineering, Chemical Engineering (Biochemical Engineering), Chemical Engineering (Environmental Engineering), Chemical Engineering (Petroleum Engineering), Chemical Engineering (Polymer Science), Civil Engineering, Civil Engineering (Building Science), Civil Engineering (Environmental Engineering), Computer Engineering and Computer Science, Computer Science, Electrical Engineering, Electrical Engineering (Computers), Environmental Engineering, Industrial and Systems Engineering, Mechanical Engineering, and Mechanical Engineering (Petroleum Engineering); and minor programs in Construction Planning and Management, Multimedia and Creative Technologies, Environmental Engineering, Petroleum Engineering and Polymer Science, Interactive Multimedia, Engineering Management, and Materials Science.

Graduate leading to the Master of Science in: Aerospace Engineering, Aerospace Engineering (Astronautics), Applied Mechanics, Biomedical Engineering, Biomedical Engineering (Biomedical Imaging and Telemedicine), Chemical Engineering, Civil Engineering, Computer Engineering, Computer Science, Electrical Engineering, Engineering Management, Environmental Engineering, Industrial and Systems Engineering, Integrated Media Systems, Manufacturing Engineering, Materials Engineering, Materials Science, Mechanical Engineering, Operations Research Engineering, Petroleum Engineering, and Systems Architecture and Engineering.

Graduate leading to the Master of Construction Management and the Master of Engineering in Computer-Aided Engineering.

Graduate leading to the Engineer degree in: Aerospace Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial and Systems Engineering, Materials Science, Mechanical Engineering, and Petroleum Engineering.

Graduate leading to the Doctor of Philosophy through the Graduate School.

Undergraduate Program Accreditation
The bachelor of science degrees in aerospace engineering, chemical engineering, civil engineering, electrical engineering, industrial and systems engineering, and mechanical engineering, including all of the options within each of these degrees, are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Undergraduate Degrees

Common Requirements

Certain general requirements are common to all undergraduate curricula for Bachelor of Science degrees in Engineering. These are as follows:

Total Units
A minimum total of 128 acceptable units is required to earn the Bachelor of Science in Engineering. Exceptions are: Aerospace Engineering, 129 units; Aerospace Engineering (Astronautics), 130 units; Biomedical Engineering, 128 units; Biomedical Engineering (Biochemical Engineering), 128 units; Biomedical/Electrical Engineering (combined major), 136 units; Biomedical/Mechanical Engineering (combined major), 133 units; Chemical Engineering, 132 units; Chemical Engineering (Biochemical Engineering), 136 units; Chemical Engineering (Environmental Engineering), 135 units; Chemical Engineering (Petroleum Engineering), 136 units; Civil Engineering, 131 units; Civil Engineering (Building Science), 135 units; Civil Engineering (Construction Engineering), 131 units; Civil Engineering (Environmental Engineering), 130 units; Computer Engineering and Computer Science, 132 units; Computer Science, 128 units; Electrical Engineering, 131 units; Environmental Engineering, 132 units; Industrial and Systems Engineering, 129 units; Mechanical Engineering, 128 units; and Mechanical Engineering (Petroleum Engineering), 131 units.

Not more than four units may be physical education activity courses, provided the department allows it in the program.

General Education Requirements
The university's general education program provides a coherent, integrated introduction to the breadth of knowledge you will need to consider yourself (and to be considered by other people) a generally well-educated person. This new program requires six courses in different categories, plus writing and diversity requirements, which are described in detail on pages 169 through 175. In addition, students pursuing a degree in computer science must meet the foreign language requirement described on page 172.

The Provost has allowed an exception to the rules governing the new general education program for students in the School of Engineering, who may elect to satisfy the requirement for Category IV with a "wild card" course, which may be a second course in Categories I, II or VI, or with an approved Advanced Placement credit toward a second course in Category VI, rather than a course in Category IV.

Students in the engineering "3-2" program are not required to satisfy the new requirements; these students are understood to have satisfied USC's general education requirements when they have satisfied the general education requirements at their previous institution.

Students in aerospace and mechanical engineering are required to register for particular sections of WRIT 140, which will be affiliated with courses other than those in the Social Issues category.

Those engineering students who are eligible to follow the "transitional" general education plan may count PHYS 151L and 152L toward Categories III and IV.

In all other respects, students in the School of Engineering must satisfy the general education requirements as described on pages 169 through 175.

Mathematics (16 units minimum)
Sixteen units or more, including three semesters of calculus, are required.

Basic Sciences (12 units minimum)
Twelve units or more of biology, chemistry or physics are required.

Residence Requirement
All students must complete a minimum of 64 units at USC in order to receive a USC degree. In addition, the School of Engineering requires that students complete all upper division units required for the major in residence.

For students in the School of Engineering "3-2" Program, at least 48 units must be earned in courses taken at USC.

Scholarship Requirement in Major Subject
For graduation with a bachelor's degree, a grade point average of C (2.0) or higher is required in all upper division courses taken in the major department including any approved substitutes for these courses taken at USC. Additional scholarship requirements for the various majors are listed under the departmental headings.

Grade Point Requirement
A grade point average of at least 2.0 is required on all course work attempted at USC.

Transfer students must meet these averages, both on residence work attempted and on combined transferred and residence courses attempted.

Probation/Disqualification
A student whose overall GPA falls below 2.0 is placed on academic probation. Continued enrollment requires clearance from an academic review counselor. Students on probation are encouraged to utilize the academic services provided by the Engineering Student Affairs Office (advisement and free tutoring).

Each semester, students on academic probation are required to receive academic advisement. Proof of advisement must be filed with the Academic Review Department before any registration requests will be processed. The only acceptable proof of advisement is an official Academic Review Advisement Record signed by the student's academic advisor and a representative from the Engineering Student Affairs Office. Academic Review Advisement forms may be obtained from Olin Hall of Engineering 106 or Student Administrative Services Building 113.

Students on academic probation who do not raise their overall GPA to 2.0 after two semesters of enrollment (excluding summers) will be academically disqualified from the university. However, if a student earns a minimum semester GPA of 2.3 in the second or any subsequent probation semester but has not yet reached an overall 2.0 GPA, the student will not be disqualified and will be allowed to enroll an additional semester.

Petitions for readmission after academic disqualification are initiated by the student through the Academic Review Department. All grade issues (IN, MG, etc.) must be resolved prior to the submission of such a petition. Before petitioning for readmission, a student must complete a minimum of 12 semester units of transferable course work (applicable to USC degree requirements) with a minimum 3.0 GPA. University residency requirements will determine whether these units are accepted as transfer credit.

As readmission to the university is never guaranteed, any indication of strong academic performance beyond the 12 unit minimum would strengthen a readmission petition.

Students must petition for readmission by December 30 for the spring semester and by May 1 for the fall semester. Late petitions will not be accepted. A non-refundable $50 fee must accompany all readmission petitions.

Special Educational Opportunities

Engineering Student Affairs Office
The Engineering Student Affairs Office, located in Olin Hall of Engineering (OHE) 106, begins to assist students as soon as they express an interest in engineering and continues working with them until, and in some cases after, they graduate.

The office is not only responsible for working with prospective students, but with continuing students as well. It directs special services and programs, provides a variety of support services, sponsors student organizations, is involved with student government and acts as a liaison with other university offices.

In short, the office enables engineering students to have a successful experience at USC. To help students become acquainted with its services, the office holds an annual welcome reception the week before fall classes where students have an opportunity to meet staff members, faculty and other engineering students.

Minority Engineering Program
The Minority Engineering Program (MEP) provides a variety of services for African-American, Hispanic and Native American students. Freshmen can participate in a summer transition-to-college program ("Summer Bridge") prior to their first semester at USC and enroll in the "Transition to Engineering" class in the fall.

Contact the Minority Engineering Program at (213) 740-1999 for more information.

Merit Research Program
Every year, a select group of promising incoming freshmen are invited by faculty to work on projects in their research laboratories. These student researchers actively participate in the development of new technology throughout their undergraduate careers.

In addition to giving students excellent first-hand experience, this program can help offset the cost of education; each participant earns an annual stipend for his or her work. This renewable award is separate from other financial assistance offered by the university.

The student must apply for renewal of his or her award by March 1 of each year.

Engineering Career Services
The School of Engineering provides extensive career services to its students. Students are encouraged to register with Engineering Career Services their first year at USC. By doing so, they will be kept informed of all career-related events such as company information sessions, resume writing workshops, mock interviews, industry luncheons and career fairs. In addition, students are able to participate in the school's extensive on-campus interview program.

USC's School of Engineering attracts employers not only from Southern California, but from across the country. A few of the many companies that have recently hired Co-ops, interns and permanent employees from USC Engineering include:

Activision, Andersen Consulting, Dolby Labs, GM Hughes Electronics, Harley-Davidson, IBM, Intel, Jet Propulsion Laboratory (JPL), Kiewit Pacific Company, Microsoft, Motorola, Northrop Grumman, Parsons, Silicon Graphics,Texas Instruments, Turner Construction Company, Universal Studios Rec. Group and Walt Disney Imagineering.

Cooperative Education
By participating in the Co-op Program, students can earn degree credit and a year's worth of industry work experience before they graduate. Co-op improves students' understanding of the relationship between theory and practice, helps them fine tune their career goals and aids in the acquisition of important engineering skills. Students' work assignments are closely related to their specific degree program and are appropriate to their current academic level.

Participation in the program is open to all full-time undergraduate engineering majors. Students are eligible to apply for Co-op the second semester of their sophomore year. Though the sequence may vary, students typically have two summer work experiences in addition to one semester immediately preceding or following one of the summer sessions. While on assignment, students enroll in a 1-2 unit course (ENGR 395) that aids in the integration of both on-campus and off-campus learning. With departmental approval, credit toward a degree may be earned upon completion of this course.

Alumni Mentor Program
The Alumni Mentor Program pairs students with engineering alumni who have similar academic and social interests, and who can address the questions students may have about the realities of engineering outside the classroom.

Freshman Mentoring Program
To ease the transition from high school to college, the School of Engineering offers a freshman mentoring program that pairs students with either a faculty, staff or upper-division student mentor. The program sponsors both academic and social events throughout the year.

3-2 Program
For those students wishing greater depth and breadth in the liberal arts, the School of Engineering developed plans with more than 20 liberal arts colleges nationwide in which a student attends a liberal arts institution for his or her first three years of college, pursuing pre-engineering courses in addition to a solid program in the liberal arts. At the end of the three years, upon recommendation from the liberal arts college, the student enters the School of Engineering as a junior and, in two years, completes the remaining requirements for a B.S. degree. After these five years are complete, the student will receive two degrees — a B.A. from the liberal arts college and a B.S. from USC.

Engineering Overseas Programs
Every other summer the School of Engineering sponsors a six-week academic program in either London or Paris which provides students with the opportunity to enroll in engineering and humanities courses, as well as participate in a directed studies project with an international engineering firm. This program is open to all engineering majors.

Honor Societies
The School of Engineering has established a variety of honor societies to recognize academic excellence, creativity and service. These are: Alpha Pi Mu (Industrial and Systems Engineering), Chi Epsilon (Civil Engineering), Eta Kappa Nu (Electrical Engineering), Omega Chi Epsilon (Chemical Engineering), Omega Rho (Industrial and Systems Engineering), Pi Tau Sigma (Mechanical Engineering), Sigma Gamma Tau (Aerospace Engineering), Tau Beta Pi (Nationwide Honor Society), Upsilon Pi Epsilon (Computer Science).

Graduate Degrees

General Requirements

All graduate work in the School of Engineering is under the jurisdiction of the School of Engineering except the Doctor of Philosophy degree, which is under the jurisdiction of the USC Graduate School. All prospective graduate engineering students should apply to the USC Office of Graduate Admission.

Admission
The School of Engineering recommends candidates for the Master of Science degree in aerospace, biomedical, biomedical (biomedical imaging), chemical, civil, electrical, engineering management, environmental, industrial and systems, manufacturing, materials, mechanical, ocean and petroleum engineering, applied mechanics, computer engineering, computer science, operations research, materials science, and systems architecture and engineering.

Two classes of students are admitted to take courses for graduate credit: admitted and conditionally admitted students. These classifications are determined by the Office of Admission on the recommendations of the appropriate department in the School of Engineering.

Admitted Students This is the status of a graduate student pursuing work leading toward an advanced degree. The student has been accepted into the degree program without any conditions.

Conditionally Admitted The chair of a major department in the School of Engineering may recommend that a student be admitted under certain conditions. Conditional admission is granted when a student's admission records are incomplete or when deficiency courses must be taken but the student appears to be otherwise admissible. The conditions must be met before the completion of two semesters of enrollment or 12 units of course work, whichever comes first, except electrical engineering, which allows only one semester. If the conditions on admission are not met within the given time period, the student may not be allowed to register for course work in subsequent semesters. When the conditions have been met, the academic department will remove the restrictions that have been placed on the student's registration.

Applicants to graduate programs must present credentials to the Office of Graduate Admission showing that they have completed an acceptable program for the bachelor's degree if their degree objective is a Master of Science and an acceptable curriculum for a Master of Science degree if the degree objective is the Engineer degree or the Doctor of Philosophy. In some departments students with outstanding records will be admitted for the doctoral program without first receiving the Master of Science degree. If the previous degree is not in the field in which the student wishes to pursue graduate study, it may be necessary to make up undergraduate deficiencies in the area of the desired specialty. Applicants must take the Graduate Record Examinations. Satisfactory scores on both the general and subject tests are required for admission to full graduate standing in most programs. At least the Graduate Record Examinations general test must be taken for admission consideration. The Graduate Record Examinations subject test may be taken in engineering or in other areas approved by the various departments. Consult the department office for further information.

Criteria
In order to qualify for admission, applicants are expected to present strong academic records and show superior accomplishment in their engineering courses. Admission decisions will be based on Graduate Record Examinations test scores and transcripts of previous school work. Individual departments may set higher admission standards than the Office of Graduate Admission or the Graduate School. In some departments letters of recommendation are required and should be sent directly to the department office. Applicants who have published professional papers in their field may forward copies to the department, and they will be considered together with the other credentials submitted.

Procedure
Once the application for admission has been sent, arrangements should be made immediately to have official transcripts of all previous undergraduate and graduate school work forwarded directly to the USC Office of Graduate Admission from the schools attended. If the Graduate Record Examinations general and subject tests have been taken, the scores should be sent to the Office of Admission by arrangement with the Educational Testing Service. If the tests have not been taken, the applicant should register to take them on the earliest available date. The departments will review the application files and select for admission those students offering the greatest promise for completing graduate studies.

General Requirements for the Master of Science
Residence Requirements
The normal time required for earning a Master of Science degree is one and one-half academic years. Students entering the School of Engineering with course or credit deficiencies require a correspondingly longer period. A candidate must complete the last four semester units of course work at USC. Four transferred units will be accepted from another engineering school with the approval of the major department.

Prerequisites
Prerequisite is a bachelor's degree in engineering, allied fields or science. If the graduate field is different from the field of the bachelor's degree, there may be undergraduate deficiencies assigned by the major department, and these must be made up by taking and passing either the assigned courses or the final examination in these courses before proceeding with the graduate courses.

Grade Point Average Requirements
A grade point average (GPA) of 3.0 (A = 4.0) is required for the master's degree in all engineering programs. The minimum GPA must be earned on all course work applied toward the master's degree and on all 400-level and above course work attempted at USC beyond the bachelor's degree. A minimum grade of C (2.0) is required in a course to receive graduate credit. Work graded C- or below is not acceptable for subject or unit credit toward any graduate degree. Transfer units count as credit (CR) toward the master's degree and are not computed in the grade point average.

There are two programs for the master's degree, one requiring a thesis and the other additional course work. Courses are selected to fit the special needs of individual students, must form an integrated program leading to a definite objective and must be approved in advance by the department. Only courses numbered 400 and above may be applied for degree credit.

Program with Thesis
The minimum requirement is 27 units; four of these units are to be thesis. At least 16 units, not including thesis, must be at the 500 level or higher, and at least 18 units must be in the major department. A total of not less than four nor more than eight units of 590 Research and 594ab Thesis must be included in the program. The minimum thesis requirement in 594a is two units; in 594b, two units.

Program without Thesis
The minimum requirement is 27 units; 18 of these units must be at the 500 level in the major department and closely related departments. Specific requirements are listed under each department.

Master's Thesis
The thesis, when it is required, is regarded as an important part of the work of the candidate for a master's degree. It is not intended to be a piece of highly recondite research, but it must be a serious, considerable and publishable piece of work demonstrating the writer's power of original thought, thorough grasp of the subject matter and ability to present material in a scholarly manner and style.

The thesis presents the results of an investigation of an approved subject in the major department. It is supervised throughout by a thesis committee, appointed by the chair of the student's major department. The committee is usually composed of two members of the major department and one other member of the faculty.

The student will register in courses 594a and b respectively during the final two semesters of the master's program as determined by discussion with an advisor. (Concurrent registration for 594a and b during the same semester is permitted when a student's progress makes completion of all requirements likely within one semester.) If the thesis has not been completed within these two semesters, the candidate must register for 594z each semester until the thesis has been accepted but no additional unit credit will be earned.

A student readmitted to candidacy by petition to the graduate study committee must reregister for 594a and 594b. Final acceptance of the thesis is based upon the recommendation of all members of the thesis committee. For requirements concerning format of master's thesis see the Graduate School section of this catalogue.

Candidates who find it necessary to be excused from registration in 594a or 594b for a semester must formally report before the beginning of the semester to the Graduate Study Office that they will be inactive during that semester and request a leave of absence. During a leave of absence a candidate will not be entitled to assistance from the thesis committee or to the use of university facilities. The granting of a leave of absence does not change the candidate's responsibility for meeting the time schedule for the completion of degree requirements. Leave will be granted only under exceptional circumstances.

Time Limit
It is expected that work for a Master of Science in engineering will be completed within a maximum of five calendar years. An academic department may grant an extension of up to one year at a time for a maximum of two years. Courses taken more than seven years prior to the date upon which the degree is to be awarded cannot be included for the degree.

Admission to Candidacy
Application for admission to candidacy for the Master of Science is a separate step from admission to graduate standing. The requirements for admission to candidacy are: (1) the applicant must be admitted to regular graduate standing and must have removed all undergraduate deficiencies, and (2) the applicant must submit a complete program approved by the major department showing the course work, research and thesis (if required).

Application for graduation should be made at the beginning of the semester in which the requirements for the master's degree are to be completed. Students are strongly advised to file for graduation as soon as the registration process has been completed so that their names may appear in the printed Commencement program and so that any discrepancies in their records may be resolved. Late filing may delay conferral of the degree.

Application forms for graduation with the master's degree may be obtained from the School of Engineering Graduate Study Office, Room 330G, Olin Hall. The office is open from 8:30 to 5:00 Monday through Friday. This application, properly endorsed by the chair of the department in which the major work is being done, should be returned to the Graduate Study Office. Changes in the program after admission to candidacy are made by petition to the graduate study committee.

Second Master's Degree
A graduate student who already holds a master's degree from USC or another acceptable engineering school in a related field may apply a limited number of previously earned units toward the second master's degree. The maximum number of units allowed for transfer is four. In all cases, permission of the chair of the major department is required. All credit, including the units from the first master's degree, must be earned within seven calendar years.

General Requirements for the Engineer Degree
The Engineer degree is awarded under jurisdiction of the School of Engineering. This degree is granted upon completion of a comprehensive curriculum beyond the general course requirements for the Master of Science and after successfully passing an engineer's qualifying examination. The required curriculum is intended to give students broad preparation in two areas of engineering, together with a minimum number of units in these areas to prepare them for the interdisciplinary nature of the many complex problems they will encounter in practice today. The degree is intended also to fulfill a growing need by industry for students with comprehensive advanced engineering training, but not necessarily with the research orientation developed by the Ph.D. student.

The Engineer degree is offered in aerospace, chemical, civil, electrical, industrial and systems, mechanical, petroleum engineering and materials science.

Prerequisites
There are three basic prerequisites for the Engineer Degree Program: a Master of Science degree or completion of 27 units of acceptable course work, application for admission to the School of Engineering and acceptance to the program by the appropriate department.

Course Requirements
The Engineer degree requires a minimum of 30 units of graduate course work beyond the Master of Science degree; up to six units at the 400 level may be counted at the discretion of the student's guidance committee if the committee finds them necessary for the student's program. The course work must form a balanced program of study leading to a definite concentration in two fields of engineering, a minimum of 12 units in one field, nine in another; nine units are elective and may be taken outside the School of Engineering, but must be acceptable for graduate credit. The distribution of course work will be governed by the student's guidance committee and should be considered in conjunction with the course work done for the Master of Science degree. A candidate for the Engineer degree may substitute a project under the supervision of a faculty member for six units of course work. In order to have the project credited toward the degree, the student must register in 690 during the course of the project; total 690 registration should be six units. A student wishing to work on a project must make arrangements with a member of the faculty to supervise and evaluate work, and obtain the approval of the committee chair prior to completing more than 15 units of course work. In many cases the project may be related to the candidate's work outside the university but must still be supervised by a faculty member. Distribution of the course work should take into account the nature of the project.

Grade Point Average Requirement
A minimum grade point average of 3.0 must be earned on all course work applied toward the Engineer degree. This average must also be achieved on all 400-level and above course work attempted at USC beyond the bachelor's degree. A minimum grade of C (2.0) is required in a course to receive graduate credit. Work graded C- or below is not acceptable for subject or unit credit toward any graduate degree. Transfer units count as credit (CR) toward the Engineer degree and are not computed in the grade point average.

Residence Requirements
A candidate must complete the last four units of course work at USC. At least 26 units must be taken in residency at USC. A maximum of four transfer units not counted toward a previous degree may be allowed with advisor approval.

Guidance Committee
After being granted graduate standing the student must form a guidance committee. The committee is made up of three full-time faculty members who are specialists in the student's areas of concentration, with at least two from the major department. Forms for appointment of the committee are available from the Graduate Study Office. The student is responsible for finding a faculty member from one area of concentration who will act as the chair of the guidance committee. The chair will assist in selection of the other members. Advisement of the student after formation of the committee will be by the committee chair.

Qualifying Examination
The student must satisfactorily complete an engineer's qualifying examination administered by his or her guidance committee. This examination will cover both areas of concentration and will consist of at least one written and one oral examination. This examination is normally taken during the last semester of course work toward the degree. Students who choose to take the examination in the semester following the completion of course requirements may do so up until the end of the third week of classes without registering. After that date they must register for GRSC 800 to maintain continuous enrollment in the program. Results of the examination are reported to the Graduate Study Office and forwarded to the Office of Academic Records and Registrar.

Transfer Credits
Four units of graduate course work may be transferred from an accredited institution to be applied toward the Engineer degree. Transfer work must have been done after receipt of the Master of Science degree and must be approved by the guidance committee.

Reserving Course Credit
A student who receives the Master of Science degree at USC may reserve a limited number of units taken prior to the receipt of the Master of Science degree for credit toward the Engineer degree. To reserve credit, the course must have been taken during the last semester as a Master of Science candidate, not used toward the Master of Science degree, be acceptable to the student's committee, and approved by petition to the graduate study committee of the School of Engineering.

Time Limit
The student must complete all requirements within five calendar years.

Admission to Candidacy
After satisfactorily completing the qualifying examination, and no later than the beginning of the last semester of course work, the student must file for candidacy. This is a separate and distinct step which sets forth the entire academic program fulfilling the degree requirements and is used as a working basis for awarding the degree.

Transfer to Doctor of Philosophy Program
Students registered for the Engineer degree may still elect to undertake a Doctor of Philosophy program. A supplemental Application for Graduate Admission must be filed with the Office of Admission.

General Requirements for the Doctor of Philosophy
This degree is granted under the jurisdiction of the USC Graduate School. Students should also refer to the Requirements for Graduation section and the Graduate School section of this catalogue for general regulations. All courses applied toward the degree must be courses accepted by the Graduate School.

Twelve Doctor of Philosophy (Ph.D.) programs are offered: aerospace engineering, biomedical engineering, chemical engineering, civil engineering, computer engineering, computer science, electrical engineering, engineering (environmental engineering), industrial and systems engineering, materials science, mechanical engineering, and petroleum engineering.

Foreign Language Requirements
There is no foreign language requirement for engineering majors.

Course Requirements
Satisfactory completion of at least 60 units of approved graduate level course work with a cumulative grade point average of at least 3.0 is required of all Ph.D. students in engineering. A minimum grade of C (2.0) is required in a course to receive graduate credit. Work graded C- or below is not acceptable for subject or unit credit toward any graduate degree. Undergraduate prerequisites and graduate course work will be required in accordance with the regulations of the major department or program and the recommendations of the student's guidance committee. Transfer units are subject to approval by the Degree Progress Department (for course work taken at institutions in the U.S.) or by International Admission (for course work taken at institutions outside the U.S.) and by the guidance committee.

Screening Procedure
The original admission decision admitting a student to the Ph.D. program is based on the student's previous academic records, Graduate Record Examinations scores and other evidence of scholastic abilities indicating promise for completing graduate studies. It is also a prerequisite that all Ph.D. students successfully complete the screening procedures designated by the department. These usually consist of a written and an oral examination administered by the faculty. Students who fail the screening procedure will be advised that they are not recommended to continue in the Ph.D. program and that any additional work may not be counted toward the degree.

Guidance Committee
The Ph.D. student's program of study is supervised by the guidance committee, which is formed immediately after passing the screening examination. The committee consists of five tenure-track faculty members, four from the major department and one from outside the department representing the minor area. Reporting the screening procedures and forming the guidance committee are accomplished by filing the appropriate forms obtainable in the Graduate School Student Services Office, Grace Ford Salvatori Hall 315.

Qualifying Examinations
The qualifying examinations are taken during the last semester of the second year of graduate study or, at the latest, in the fifth semester or equivalent. The Request to take the Qualifying Examinations must be filed in the semester prior to taking the examinations and at least 30 days before beginning the examinations. The examinations are intended to determine the extent of the student's knowledge in basic science and engineering areas as well as the ability to do original and scholarly research. The guidance committee decides the nature of the qualifying examinations (both oral and written portions) according to the policies applicable in each department.

The examinations may be scheduled at any time during the semester provided that all members of the committee are available to administer them. All portions of the examinations must be completed within 60 days. After passing the qualifying examinations the Ph.D. student is admitted to candidacy by the Dean of Graduate Studies and the dissertation committee is established. After this step students will normally engage in at least one year of full-time graduate study and research on campus.

Doctoral Dissertation
An acceptable dissertation based on original investigation and supervised directly by the dissertation committee is required. The dissertation must show mastery of a special field, capacity for independent research and a scholarly result. Candidates are expected to keep all members of the dissertation committee informed of their progress at all stages of the dissertation.

Defense of the Dissertation
After satisfactorily meeting all other requirements and after the research and writing of the dissertation are substantially complete, the Ph.D. candidate must pass a general final oral examination devoted to the major field and to the topic of the dissertation. The examination will be conducted in such a manner as to determine to the satisfaction of the dissertation committee that the candidate has attained the stage of scholarly advancement and power of investigation demanded by the university for final recommendation to the doctorate. The faculty are invited to attend and to participate in the final oral examination. However, only the dissertation committee may vote. Unanimous approval of the committee is required for the student to proceed to final typing of the dissertation.

Departmental Requirements
The requirements and regulations set forth in this portion of the catalogue are to be construed as the minimal requirements only as established by the Graduate School. In addition, students must meet all the requirements established by their department.

Engineering

The courses listed in the following section have been designed for specific groups of students for various purposes as indicated in the course descriptions. Certain courses have restrictions related to their applicability for degree credit. Students should consult the academic advisor in the major department for further information.

Courses of Instruction

ENGINEERING (ENGR)

040x Freshman Engineering Transition (1, Fa) Introduction to the School of Engineering: career objectives, study skills, available resources, and employment counseling. Graded CR/NC. Not available for degree credit.

100abcd Engineering Honors Colloquium (1-1-1-1) Recent developments in a highly technological society with emphasis on selected topics. Enrollment limited to members of the School of Engineering Honors Program. Graded CR/NC.

101 Introduction to Engineering (3, Fa) Gateway to the majors and minors in engineering. Introduction to engineering disciplines. Historical and current trends in engineering; ethical and societal factors in engineering solutions. Hands-on design experiences; field trips; USC laboratory tours.

301 Technical Entrepreneurship (3) (Enroll in BUAD 301)

352x Sociotechnical Problem Solving and Design (4) Different modes of reasoning for different problem types; tools and concepts for handling ill-structured sociotechnical problems and complex systems; applications and projects in diverse fields. Not available for major credit to engineering majors. *Prerequisite:* junior standing.

395abcdx Cooperative Education Work Experience (1 or 2, max 5) Supervised work experience in a professional environment related to a specific degree program, academic level, and career objective. Acceptance into Cooperative Education Program required. Graded IP/CR/NC. Degree credit by departmental approval.

493x Dean's Seminar in Entrepreneurship (2) (Enroll in BUAD 493*x*)

499 Special Topics (2-4, max 8) Current developments in the field of engineering.

580L Modern Manufacturing Technologies (4, Sp) Presentation of hardware and software technologies in modern manufacturing including CAD, numerical control, process planning, robotics, and factory automation using a laboratory-oriented approach. Recommended preparation: manufacturing processes, probability, statistics, computer programming.

581ab Manufacturing Engineering Internship (3-3, FaSpSm) Internship experience providing important hands-on experience in technology and management in manufacturing systems. Only required of students eligible. Graded CR/NC. *Corequisite:* ISE 517.

595 Manufacturing Engineering Seminar (3) Topics on the design, integration and operation of manufacturing enterprises and their role in an organization. Lectures, case studies, speaker sessions, field trips, team projects, reports and presentations. *Prerequisite:* EE 561, ISE 511*L*, and ME 583.

Aerospace and Mechanical Engineering

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Chair: Richard E. Kaplan, Sc.D.

Associate Chair: Satwindar S. Sadhal, Ph.D.

Faculty

David Packard Chair in Manufacturing Engineering: Stephen C-Y Lu, Ph.D. (*Industrial and System Engineering*)

Arthur B. Freeman Professorship in Engineering: E. Phillip Muntz, Ph.D.** (*Radiology*)

Smith International Professorship in Mechanical Engineering: Tony Maxworthy, Ph.D.**

Professors: Ron F. Blackwelder, Ph.D.*; Richard S. Bucy, Ph.D. (*Mathematics*); Frederick K. Browand, Ph.D.; Charles Campbell, Ph.D.; Julian Domaradzki, Ph.D.; Marijan Dravinski, Ph.D.; Henryk Flashner, Ph.D.; Michael Gruntman, Ph.D.; Richard E. Kaplan, Sc.D.; Joseph Kunc, Ph.D. (*Physics*); Terence G. Langdon, Ph.D., D.Sc. (*Materials Science and Geological Sciences*); Stephen C-Y Lu, Ph.D. (*Industrial and System Engineering*); Sami F. Masri, Ph.D. (*Civil Engineering*); Tony Maxworthy, Ph.D.**; Eckart H. Meiburg, Ph.D.; E. Phillip Muntz, Ph.D.** (*Radiology*); Paul K. Newton, Ph.D.; Steven Nutt, Ph.D. (*Materials Science*); Larry G. Redekopp, Ph.D.*; Satwindar S. Sadhal, Ph.D.; Donald E. Shemansky, Ph.D.; Costas Synolakis, Ph.D. (*Civil Engineering*); Firdaus E. Udwadia, Ph.D. (*Civil Engineering and Decision Systems*)

Associate Professors: Fokion Egolfopoulos, Ph.D.; Daniel Erwin, Ph.D.; Yan Jin, Ph.D.; Paul Ronney, Ph.D.; Geoffrey R. Shiflett, Ph.D.*; Geoffrey Spedding, Ph.D.; Bingen Yang, Ph.D.

Adjunct Professors: Robert Brodsky, Ph.D.; Gerald Hintz, Ph.D.; Robert H. Liebeck, Ph.D.; John McIntyre, Ph.D.; Peter Lissaman, Ph.D.; M. Oussama Safadi, Ph.D.; Eugene H. Trinh, Ph.D.; James Wertz, Ph.D.

Research Associate Professors: Ramesh Guttalu, Ph.D.; Hussein Youssef, Ph.D.; Siavash Narimousa, Ph.D.

Research Assistant Professors: Kyaw T. Aung, Ph.D.; Darek Bogucki, Ph.D.; Michael R. Bryant, Ph.D. (*Ophthalmology*); Mustapha Hammache, Ph.D.; Fu-Sheng Ho, Ph.D.; Xianming Liu, Ph.D.; Howard Pearlman, Ph.D.

Research Associates: Jun Kuang, Ph.D.; Jianbang Liu; Mark Michaelian, Ph.D.; Alexandre V. Pesterev, Ph.D.; Lars Sitzki, Ph.D.; Mingde Song, Ph.D.; Shirun Yang, Ph.D.

Lecturers: Blaine Beron-Rawdon; Johnny Kwok, Ph.D.; Mark Page; Robert D. Parker, Ph.D.; Madhu Thangavelu, M.S.; Alan Tribble, Ph.D.; Jacob Van Zyl, Ph.D.; David Wallerstein, Ph.D.; Joseph J. Wang, Ph.D.; David Wilcox, Ph.D.

Emeritus Professors: P. Roy Choudhury, Ph.D.*; C. Roger Freberg, Ph.D.*; Melvin Gerstein, Ph.D.; Clarke Howatt, M.S.; S. Lampert, Ph.D.; Robert Mannes, M.S., P.E.*; Eberhardt Rechtin, Ph.D. (*Electrical Engineering and Industrial and Systems Engineering*); Martin Siegel, M.S., P.E.; B. Andreas Troesch, Ph.D.; James Vernon, N.I.S.M.E.; Hsun-Tiao Yang, Ph.D.

Distinguished Emeritus Professor: Hsien Kei Cheng, Ph.D.

*Recipient of university-wide or school teaching award.

**Recipient of university-wide or school research award.

Mechanical Engineering Honor Society: Pi Tau Sigma

Aerospace Engineering Honor Society: Sigma Gamma Tau

Degree Requirements

Program Goals

The undergraduate programs in Aerospace and Mechanical Engineering have the following objectives:

(1) Graduates will be prepared with an education in mathmatics, science, engineering and computational methods to be able to apply the fundamental principles to deal with problems in engineering.

(2) Education for undergraduates will cover both fundamental and applied sciences to prepare them for a professional engineering career or for entry to graduate schools.

(3) Graduates will be provided with sufficient preparation to integrate the fundamental principles with engineering design requirements, fully implementing modern tools such as digital computers and state-of-the-art laboratory equipment.

(4) Students will be given the education and the capability to analyze, design and build systems based on demands in both small- and large-scale industries.

(5) Students will be provided with a balanced education covering the technical areas together with the required general education and engineering economics to produce competent technical innovators, as well as industrial leaders.

(6) Students will be given a curriculum with sufficient diversity so that the graduating senior will have the necessary background to handle societal, ethical and environmental issues affecting technical decisions. Graduates will be prepared with communication skills to effectively deal with and work with persons and teams of diverse technical and nontechnical backgrounds.

Bachelor of Science in Aerospace Engineering

The requirement for this degree is 128 or 129 units. A grade point average of C (2.0) is required in all upper division courses taken in Engineering departments and all departments of science and mathematics. See common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
AE 105	Introduction to Aerospace Engineering	4
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
WRIT 140	Writing and Critical Reasoning	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
AE 150L	Introduction to Aerospace Engineering Analysis	4
MATH 126	Calculus II	4
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics	4
General education	Social Issues	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
AME 203	Mechanics I	5
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		17

SECOND YEAR, SECOND SEMESTER		UNITS
AE 282	Astronautics and Space Environment I	3
AE 261	Basic Flight Mechanics	4
AME 205	Mechanics II	5
MATH 245	Mathematics of Physics and Engineering I	4
		16

THIRD YEAR, FIRST SEMESTER		UNITS
AME 341aL	Mechoptronics Laboratory I	3
ME 310	Engineering Thermodynamics I	3
ME 404	Mechanical Engineering Problems	3
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
AE 309	Dynamics of Fluids	4
AME 308	Computer-Aided Analyses for Aero-Mechanical Design	3
AME 341bL	Mechoptronics Laboratory II	3
General education		4
		14

FOURTH YEAR, FIRST SEMESTER		UNITS
AE 441aL	Senior Projects Laboratory	3
AME 400	Senior Seminar	1
ME 451	Linear Control Systems I	3
Electives	AE Core**	6
Elective	technical***	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
AE 481	Aircraft Design, or	
AE 482	Spacecraft Design	3-4
Elective	AE Core**	3
Elective	technical***	3
WRIT 340	Advanced Writing	3
General education		4
		16-17
Total units:		128-129

*Satisfies general education Category III.

**Any upper division AE courses.

***Technical electives consist of (1) any upper division course in engineering except CE 404, CE 412, ISE 440 and ENGR 300, or (2) an upper division course in chemistry, physics or mathematics and MATH 225. No more than three units of 490 course work can be used to satisfy the technical elective requirement.

Bachelor of Science in Aerospace Engineering (Astronautics)

The Bachelor of Science in Aerospace Engineering (Astronautics) prepares students for engineering careers in the space sector of the aerospace industry; for research and development in industry and government centers and laboratories; and for graduate study. The program provides a core in the fundamentals of aerospace engineering; specialized work in astronautics and space technology; and technical electives to broaden and/or deepen the course work.

This area of emphasis (so designated on the transcript) requires completion of the following course of study.

FIRST YEAR, FIRST SEMESTER

AE 105	Introduction to Aerospace Engineering	4
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
WRIT 140	Writing and Critical Reasoning	4
		16

FIRST YEAR, SECOND SEMESTER

MATH 126	Calculus II	4
ME 150L	Introduction to Computational Methods in Mechanical Engineering	4
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics*	4
General education	Social Issues	4
		16

SECOND YEAR, FIRST SEMESTER

AME 203	Mechanics I	5
MATH 226	Calculus III	4
PHYS 152L	Physics II: Electricity and Magnetism	4
General education		4
		17

SECOND YEAR, SECOND SEMESTER

AE 282	Astronautics and Space Environment I	3
AME 205	Mechanics II	5
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Physics III: Optics and Modern Physics	4
		16

THIRD YEAR, FIRST SEMESTER

AE 311a	Thermal and Statistical Systems	3
AE 382	Astronautics and Space Environment II	3
AME 341aL	Mechoptronics Laboratory I	3
ME 404	Mechanical Engineering Problems	3
General education		4
		16

THIRD YEAR, SECOND SEMESTER

AE 311b	Thermal and Statistical Systems	3
AME 308	Computer-Aided Analyses for Aero-Mechanical Design	3
AME 341bL	Mechoptronics Laboratory II	3
WRIT 340	Advanced Writing	3
General education		4
		16

FOURTH YEAR, FIRST SEMESTER

AE 441aL	Senior Projects Laboratory	3
AE 473	Spacecraft Propulsion	3
AME 400	Senior Seminar	1
ME 451	Linear Control Systems I	3
Elective	Technical elective	6
		16

FOURTH YEAR, SECOND SEMESTER

AE 482	Spacecraft Design	4
AE 483	Spacecraft Dynamics	3
AE 485	Molecular Gas Dynamics	3
Elective	Technical elective	3
General education		4
		17

* Satisfies general education Category III.

Master of Science in Aerospace Engineering

In addition to the general requirements listed in this catalogue, the department has identified requirements in the following areas of specialization: aerodynamics/fluid dynamics; aerospace controls; aerospace design; aerospace structures; astronautics; computational fluid dynamics; hypersonics/kinetics of gases and plasmas; propulsion; and space science. Core requirements and elective requirements are defined for each area of specialization. Information on the current approved courses which comprise these core and elective requirements is available from the department.

Master of Science in Aerospace Engineering (Astronautics)

This degree is in a highly-dynamic and technologically advanced area of space technology. The program is designed for those with B.S. degrees in science and engineering who desire to work in the space sector of the aerospace industry, government research and development centers, and laboratories. If the applicant's degree is in science or engineering other than aerospace engineering, he or she may be required to take 1-3 upper division undergraduate classes. The program uses the USC Distance Education Network (DEN).

Application requirements are identical to those for the Master of Science in Aerospace Engineering program.

Required courses: 27 units.

CORE REQUIREMENT (6 UNITS)

AE 501	Spacecraft System Design	3
AE 585	Space Environments and Spacecraft Interactions	3

CORE ELECTIVE REQUIREMENT (CHOOSE ONE, 3 UNITS)

AE 473	Spacecraft Propulsion	3
AE 502	Systems for Remote Sensing from Space	3
AE 506	Design of Low Cost Space Missions	3
AE 508	Spacecraft Power Systems	3
AE 511	Compressible Gas Dynamics	3
AE 520a	Physical Gas Dynamics	3
AE 520b	Physical Gas Dynamics	3
AE 549a	Systems Architecting	3
AE 549b	Systems Architecting	3
AE 580	Orbital Mechanics I	3
AE 581	Orbital Mechanics II	3
AE 583	Spacecraft Attitude Dynamics	3

TECHNICAL ELECTIVE REQUIREMENT (12 UNITS)

Four, 3-unit courses. It is advisable to select these four elective courses from the list of core electives above. No more than three units of directed research (AE 590) can be applied to the 27-unit requirement.

ENGINEERING MATHEMATICS REQUIREMENT (6 UNITS)

AE 525ab	Engineering Analysis	3-3

At least 18 units must be at the 500 or 600 level.

Master of Science in Systems Architecture and Engineering

See the listing under Systems Architecture and Engineering, page 538.

Master of Engineering in Computer-Aided Engineering

The Master of Engineering program educates and trains multidisciplinary professionals in the use of computational techniques in the planning, design and management of engineering projects. The emphasized computer-aided engineering subjects are modeling, simulation, visualization, optimization, artificial intelligence and advanced design, documentation, manufacturing and information management.

The program provides the graduate with advanced education in a particular engineering subject area, associated with aerospace, civil or mechanical engineering. This advanced engineering education is coupled with an intensive concentration in computational procedures appropriate for that subject area. The program also includes substantial

project work to provide a background in the application of CAE techniques in real world situations. See the listing under Computer-Aided Engineering, page 494.

Engineer in Aerospace Engineering
Requirements for the Engineer in Aerospace Engineering are the same as the general requirements. Three to six of the units required for the degree must be AE 690. Prior approval must be obtained from the guidance committee before registration in AE 690.

Doctor of Philosophy in Aerospace Engineering
The Doctor of Philosophy with a major in aerospace engineering is also offered. See general requirements for graduate degrees.

Certificate in Aerospace Engineering (Astronautics)
The Certificate in Aerospace Engineering (Astronautics) is designed for practicing engineers and scientists who enter space-related fields and/or who want to obtain training in specific space-related areas. The students enroll at USC as limited status students. The required course work consists of 12 units; the students will choose four 3-unit courses from the following:

REQUIRED COURSES		UNITS
AE 501	Spacecraft System Design	3
AE 502	Systems for Remote Sensing from Space	3
AE 549ab	Systems Architecting	3-3
AE 580	Orbital Mechanics I	3
AE 581	Orbital Mechanics II	3
AE 583	Spacecraft Attitude Dynamics	3
AE 585	Space Environments and Spacecraft Interaction	3
AE 599	Special Topics	3

The credit for classes may be applied toward the M.S. or Ph.D. in Aerospace Engineering should the student decide later to pursue an advanced degree. In order to be admitted to the M.S. program, the student should maintain a B average or higher in courses for the certificate and must satisfy all normal admission requirements. All courses for the certificate must be taken at USC. It is anticipated that other classes on emerging space technologies will be added to the list of the offered classes in the future.

Certificate in Computer-Aided Engineering
See listing on page 494.

Mechanical Engineering Degrees
For information on mechanical engineering degrees and course requirements, see page 527.

Courses of Instruction

AEROSPACE ENGINEERING (AE)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

105 Introduction to Aerospace Engineering (4, Fa) Gateway to the Aerospace Engineering major. Introduction to flight vehicle performance and propulsion. Elements of the physics of gases. Laboratory: computers and graphics; model rocket and glider test flights.

150L Introduction to Aerospace Engineering Analysis (4, Sp) Organization of problems for computational solution; flow charts, computer programming, simultaneous linear equations, numerical methods for factoring polynomials and evaluating integrals; computer graphics; related subjects. *Corequisite:* MATH 125.

261 Basic Flight Mechanics (4, Sp) Performance of flight vehicles; maximum speed, rate-of-climb, range, and endurance; basic stability and control, weight, and balance; computer exercises. (Duplicates credit in former AE 205.) *Recommended preparation:* AME 150*L* and AME 203.

282 Astronautics and Space Environment I (3) Solar system. Two-body problem. Orbits. Hohmann transfer. Rocket equation. Space environment and its effects on space systems. Sun. Solar wind. Geomagnetic field. Atmosphere, ionosphere, magnetosphere. *Prerequisite:* MATH 226, PHYS 152*L*.

309 Dynamics of Fluids (4) Fluid statics; conservation of mass, momentum, and energy in integral and differential form; applications. Laminar and turbulent pipe flow; compressible flow; potential flow over bodies. *Recommended preparation:* AME 205 and ME 310.

311ab Thermal and Statistical Systems (3-3, FaSp) Thermodynamics and statistical mechanics. Kinetics of atoms, molecules, and photons. Compressible fluid dynamics. *Prerequisite:* MATH 245, PHYS 153*L*.

353 Aerospace Structures I (3, Fa) Shear and bending in symmetrical and unsymmetrical sections; torsion, column, and thin sheet analysis and design, including plastic failures and open section crippling. *Prerequisite:* AME 203.

380 Elements of Astronautics and Space Science (3, Sp) Sun and solar system. Spacecraft mission design; orbital maneuvers. Plasma; electromagnetic radiation. Solar wind; magnetospheres; ionospheres; magnetic storms; auroras. Elements of geophysics. Planets. Space instrumentation. *Prerequisite:* junior standing; r*ecommended preparation:* MATH 125, MATH 126, MATH 226; PHYS 151*L*, PHYS 152*L*, PHYS 153*L*.

382 Astronautics and Space Environment II (3) Basics of spacecraft dynamics. Euler's equation. Introduction to space plasma physics. Spacecraft in plasma. Radiation effects on space systems. Space instrumentation: detectors, analyzers, spectrometers. *Prerequisite:* AE 282, PHYS 153*L*.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

410 Molecular Theory of Gases (3) Molecular structure; intermolecular potentials; molecular processes in gases; molecular interpretation of concepts of classical thermodynamics; radiative transport phenomena in gases. *Prerequisite:* ME 310.

428 Mechanics of Materials (3) (Enroll in CE 428)

429 Structural Concept Design Project (3) (Enroll in CE 429)

441abL Senior Projects Laboratory (3-3) Individual engineering projects designed and constructed to model and test a physical principle or system. *Recommended preparation:* AE 341*L*.

453 Aerospace Structural Design Project (3) Synthesis of aerospace structural systems with prescribed strength and stiffness constraints; project proposals; concept generation and preliminary analysis; evaluation of alternate design approaches; project management; technical presentations. *Prerequisite:* AE 353.

457 Engineering Fluid Dynamics (3) (Enroll in ME 457)

458 Theory of Structures II (3) (Enroll in CE 458)

460 Aerodynamic Theory (3) Basic relations describing the inviscid flow field about bodies and wings moving at subsonic and supersonic speeds. *Prerequisite:* AE 309.

461 Flight Mechanics (3, Fa) Applications of basic aerodynamics to aircraft and missile performance, power and thrust, stability and control, compressibility effects. *Recommended preparation:* AE 309.

465 High-Speed Aerodynamics (3) Transonic and supersonic aerodynamics; application to high-speed airplanes. *Prerequisite:* AE 460.

473 Spacecraft Propulsion (3) Introduction to rocket engineering. Space missions and thrust requirements. Compressible gas dynamics. Propellant chemistry and thermodynamics. Liquid- and solid-fueled rockets. Nuclear and electric propulsion. *Prerequisite:* ME 310 and AE 309.

477 Solar System Exploration (3, Fa) Overview of current knowledge of solar system heliosphere, with emphasis on atmospheric and magnetospheric structure, including experimental methods of observation. *Prerequisite:* MATH 245.

481 Aircraft Design (3, Sp) Aircraft design and analysis, design requirements and specifications; integration of structure, propulsion, control system, and aerodynamic configuration; performance analysis and prediction. *Recommended preparation:* AE 205, AE 309, AE 353.

482 Spacecraft Design (4, Sp) Spacecraft mission design, space environment, attitude determination and control, telecommunications, propulsion, structures and mechanisms, thermal control, power systems, launch systems and facilities. Semester design project. Junior or senior standing in Engineering or Physics.

483 Spacecraft Dynamics (3, Sp) Two-body motion. Rigid-body motion. Attitude dynamics and maneuvers. Spacecraft stabilization: gravity gradient, reaction wheels, magnetic torques. Thruster attitude control. Senior standing.

484 Principles and Techniques of Remote Sensing (3) Remote sensing methods, techniques and accuracies, photographic systems, radar, passive microwave, infrared, visible and ultraviolet imaging, capabilities, limitations of uses. *Prerequisite:* senior standing in engineering.

485 Molecular Gas Dynamics (3) Physical description of kinetic nature of gas flows; distribution function; introduction to the Boltzmann equation; free-molecule flow; surface and molecular reflection properties; Monte-Carlo flow calculations. *Recommended preparation:* AE 309 or AE 311*b*.

486 Fundamental Processes in High Temperature Gases (3) Fundamental collisional and radiative processes (ionic, atomic, and molecular); basic concepts and principles of microscopic approach to description of physical properties of energetic gas flow. *Prerequisite:* senior standing.

490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

499 Special Topics (2-4, max 8) Course content to be selected each semester from recent developments in aerospace engineering and related fields.

501 Spacecraft System Design (3) System components; vehicle structure, propulsion systems, flight dynamics, thermal control, power systems, telecommunication. Interfaces and tradeoffs between these components. Testing, system reliability, and integration.

502 Systems for Remote Sensing from Space (3) The operation, accuracy, resolution, figures of merit, and application of instruments which either produce images of ground scenes or probe the atmosphere as viewed primarily from space. *Prerequisite:* graduate standing in engineering or physics.

503 Elements of Vehicle and Energy Systems Design (3, Irregular) Design synthesis of aero/hydro/mechanical systems; techniques of design; conceptual thinking; problem definition, configurational development, analytic engineering approximation, oral briefings and group problem solving. Graduate standing.

504 Elements of Composite Structure Design (3, Sp) Compliance, strength, endurance properties of advanced composites are developed, including semi-monocoque structure, beams, plates, panels. Applications of theory to optimal design of components and systems. Graduate standing or departmental approval required.

506 Design of Low Cost Space Missions (3, Sp) Reviews all aspects of space mission design for practical approaches to reducing cost. Examines "LightSat" mission experience and potential applicability to large-scale missions. *Prerequisite:* graduate standing in engineering or science; *recommended preparation:* AE 501 or some experience in space engineering.

507 Mechanics of Solids I (3) (Enroll in CE 507)

508 Spacecraft Power Systems (3, Sp) Introduction to solar arrays, batteries, nuclear power sources, mechanical energy storage. Application theory of operation, practical considerations. Subsystem topologies and performance. Design optimization techniques. Graduate standing in engineering or science.

510ab Dynamics of Incompressible Fluids (3-3, FaSp) A unified discussion of low-speed fluid mechanics including exact solutions; approximation techniques for low and high Reynolds numbers; inviscid flows; surface waves; dynamic stability; turbulence.

511 Compressible Gas Dynamics (3, Sp) Thermodynamics, kinetic theory, compressible flow equations, shock and expansion waves, similarity, shock-expansion techniques and linearized flow applied to bodies, characteristics, theory of boundary layers.

512 Aerodynamics of Wings and Bodies (3, Fa) Formulation of linearized theories for evaluating forces and moments on flight geometrics in subsonic and supersonic flow.

516ab Flight Vehicle Stability and Control (3-3) Response of flight to linear, nonlinear, and randomly defined disturbances. Generation and measurement of error signals in navigational systems. Stability and control techniques. *Recommended preparation:* AE 461.

520ab Physical Gas Dynamics (3-3, FaSp) *a:* Molecular structure; radiative processes; microscopic description of gas phenomena; translational, rotational, vibrational, and electronic freedom degrees; particle energy distributions; microscopic representation of thermodynamic functions. *Prerequisite:* graduate standing or departmental approval. *b:* Kinetic concepts in gas physics; thermal non-equilibrium; intermolecular potentials; transport of radiation and particles in high-temperature gas; dissociation and ionization equilibrium; energy relaxation. *Prerequisite:* AE 520*a*.

525ab Engineering Analysis (3-3, FaSp) Applied mathematics pertinent to engineering problems: vector analysis; theory of functions of a complex variable; integral transforms; eigenfunction expansions; partial differential equations; special functions.

529 Aircraft Structures Analysis (3, Sp) The direct stiffness (finite element) method for analysis of semimonocoque structures; energy methods; elasticity, plates and shells, vibration, and stability; system identification.

535ab Introduction to Computational Fluid Mechanics (3-3, FaSp) *a:* Convergence, consistency, stability: finite difference, finite element, and spectral methods; direct and iterative procedures for steady problems; linear diffusion and advection problems; nonlinear advection problems. *Prerequisite:* AE 525*b*. *b:* Generalized curvilinear coordinates; grid generation; numerical techniques for transonic and supersonic inviscid flows; boundary layer flows; reduced Navier-Stokes equations; compressible and incompressible viscous flows. *Prerequisite:* AE 535*a*; AE 510*a* or AE 511.

542 Theory of Plates (3) (Enroll in CE 542)

543 Stability of Structures (3) (Enroll in CE 543)

546 Basic Aeroelasticity (3, Irregular) Interaction of aerodynamic and structural forces. Static aeroelasticity: life effectiveness, divergence, reversal. Vibration and flutter: eigenvalues, introduction to unsteady aerodynamics. Computers: influence coefficient, modal solutions.

547 Advanced Aeroelasticity (3, Irregular) Transient, frequency, and random response: dynamic loads, atmospheric turbulence, numerical analysis, power spectral analysis; servo system interaction; unsteady compressible potential theory. *Prerequisite:* AE 546.

549ab Systems Architecting (3-3) *a:* Introduction to systems architecting in aerospace, electrical, computer, and manufacturing systems emphasizing the conceptual and acceptance phases and using heuristics; *b:* major research project. *Prerequisite:* B.S. degree in a related field of engineering; *a* before *b*.

550ab Seminar in Aerospace Engineering (1-1, FaSp) Recent developments and research in aerospace engineering and related fields. Oral and written reports. Graded CR/NC. *Prerequisite:* graduate standing.

556 Systems Architecture Design Experience (3, Sp) This course gives the student a design experience which mirrors the activities of a systems architect during the architecturing process. Interdisciplinary skills are emphasized. *Prerequisite:* AE 549*a*.

560ab Current Topics in Aerodynamics (3-3) Selected material of current engineering interest in aerospace engineering and related fields.

564 Computational Techniques in Rarefied Gas Dynamics (3, Irregular) Particle-based computational simulation methods for rarefied, high-speed flows. Molecular collision kinetics. Monte Carlo direct simulation and related techniques. *Recommended preparation:* AE 520*a* and skill in FORTRAN programming.

565 Theoretical and Computational Hypersonic Aerodynamics (3, Irregular) Introduction to concepts and features unique to high-speed flow for sustained atmospheric flight, and to current developments in asymptotic theory and numerical simulation. *Recommended preparation:* AE 511 or AE 512.

572L Experimental Engineering Projects (3) Experimental methods appropriate to engineering research, emphasizing interdisciplinary investigations. Individual projects.

575 Advanced Engineering Analysis (3) (Enroll in ME 575)

576 Advanced Engineering Analytical Methods (3) (Enroll in ME 576)

580 Orbital Mechanics I (3) Physical principles; two-body and central force motion; trajectory correction maneuvers; position and velocity in conic orbits; Lambert's problem; celestial mechanics; orbital perturbations.

581 Orbital Mechanics II (3, Fa) Theory of perturbations of orbits; numerical methods in orbital mechanics; satellite dynamics; averaging methods; resonance; mission analysis. *Prerequisite:* AE 580.

583 Spacecraft Attitude Dynamics (3) Dynamics of systems of particles and rigid bodies; spacecraft attitude systems; attitude maneuvers (spin, precession, nutation, etc.); attitude stabilization and attitude determination; simulation methods.

585 Space Environments and Spacecraft Interactions (3) Space environments and interactions with space systems. Vacuum, neutral and ionized species, plasma, radiation, micrometeoroids. Phenomena important for spacecraft operations.

586 Partially Ionized Plasmas (3) Review of microscopic processes involving particles and radiation, and their impact on properties of high-temperature gases and plasmas in local thermal equilibrium and non-equilibrium.

587 Gas-Surface Processes (3, Sp) Examination of the basic physical chemistry of the interaction of photons and low density gas phase particles with solid state materials. *Recommended preparation:* AE 585, AE 486.

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

594abz Master's Thesis (2-2-0) Credit on acceptance of thesis. Graded IP/CR/NC.

599 Special Topics (2-4, max 9) Course content will be selected each semester to reflect current trends and developments in the field of aerospace engineering.

620 Aero and Hydrodynamic Wave Theory (3) Linear and nonlinear wave motion in fluids: group velocity, dispersion, wave action, wave patterns, evolution equations, solitons and solitary waves, resonance phenomena. *Recommended preparation:* AE 525*b* and CE 309.

621 Stability of Fluids (3) Linear and nonlinear stability analysis applied to free shear layers, boundary layers and jets; Rayleigh-Benard convective instabilities and centrifugal instability of rotating flows. *Recommended preparation:* AE 510*b*.

623 Dynamics of Stratified and Rotating Flows (3) Fluid motions in which density gradients and/or rotation are important, including internal wave motions with rotation, flow past obstacles, viscous effects, singular perturbations. *Recommended preparation:* AE 510*b*.

624 The Fluid Dynamics of Natural Phenomena (3) Application of the basic concepts of rotating, stratified fluid motion to problems in meteorology, oceanography, geophysics and astrophysics.

626 Singular Perturbation Methods (3) Asymptotic series, W.K.B. approximation, method of steepest descent, stationary phase; matched asymptotic expansions and method of multiple scales applied to ordinary and partial differential equations. *Recommended preparation:* AE 525*b*.

630 Transition to Chaos in Dynamical Systems (3) Bifurcation theory and universal routes to chaos in deterministic systems; application to maps and differential flows; characterization of strange attractors. *Recommended preparation:* AE 525*b*.

640 Advanced Theory of Elasticity (3) (Enroll in CE 640)

651 Statistical Theories of Turbulence (3) Stationary stochastic processes. Isotropic turbulence; governing equations for the velocity correlation and spectrum functions. Turbulent diffusion. Scalar fluctuations in a turbulent field. *Recommended preparation:* AE 510*b*.

652 Turbulent Shear Flows (3) Free shear layers. Turbulent flows in pipes and channels. Turbulent boundary layers. Effects of compressibility. Sound radiation by turbulence. *Recommended preparation:* AE 510*b*.

690 Directed Research (1-4, max 8) Laboratory study of specific problems by candidates for the degree Engineer in Aerospace Engineering. Graded CR/NC.

694abz Thesis (2-2-0) Required for the degree Engineer in Aerospace Engineering. Credit on acceptance of thesis. Graded IP/CR/NC.

790 Research (1-12) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

AEROSPACE AND MECHANICAL ENGINEERING (AME)

203 Mechanics I (5, Fa) An integrated introduction to statics, strength of materials and design. (Duplicates credit in former ME 203.) *Recommended preparation:* PHYS 151, MATH 126.

205 Mechanics II (5, Sp) An integrated introduction to kinematics, dynamics and design. (Duplicates credit in former ME 205.) *Recommended preparation:* AME 203.

308 Computer-Aided Analyses for Aero-Mechanical Design (3, Sp) Introduction to the finite element method; practical application of computer analysis tools for structural analyses and design. (Duplicates credit in former ME 308.) *Recommended preparation:* ME 205, MATH 245.

341abL Mechoptronics Laboratory I and II (3-3, FaSp) A coordinated laboratory and lecture sequence on aeromechanical instrumentation and device control stressing the symbiotic integration of mechanical, optical and electronic components. (Duplicates credit in former AE 341*abL*.) *Prerequisite:* PHYS 152*L*, MATH 126.

400 Senior Seminar (1, Fa) Discussion of topics related to technology innovation and professional and industrial practice in aerospace and mechanical engineering. Technical communication experiences are required. Senior standing. (Duplicates credit in former ME 400.)

Applied Mechanics

Email: civileng@mizar.usc.edu

Bachelor of Science in Applied Mechanics
The requirement for this degree is 128 units. A grade point average of C (2.0) is required in all upper division engineering courses. This program is administered by the staff of the Departments of Aerospace, Civil and Mechanical Engineering. Students may register in any of those departments and still qualify for this degree. See common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL	General Chemistry	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
MATH 125	Calculus I	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
Electives	approved electives in computer programming	4
MATH 126	Calculus II	4
PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics	4
General education		4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
MATH 226	Calculus III	4
PHYS 152	Fundamentals of Physics II: Electricity and Magnetism	4
General education		8
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		15

THIRD YEAR, FIRST SEMESTER		UNITS
CE 325	Dynamics	3
EE 326L	Essentials of Electrical Engineering	4
MATH 445	Mathematics of Physics and Engineering II	4
ME 310	Engineering Thermodynamics I	3
		14

THIRD YEAR, SECOND SEMESTER		UNITS
AME 341a	Mechoptronics Laboratory I	3
CE 309	Fluid Mechanics	3
General education		4
Electives	technical	7
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
AE 441aL	Senior Projects Laboratory	3
WRIT 340	Advanced Writing	4
Electives	technical	9
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
Electives**	free electives	4
Electives	technical	12
		16

*Taken concurrently.

**The choice of free electives in the fourth year requires approval of the administering department.

Master of Science in Applied Mechanics
See the listing in the Civil Engineering section on page 488.

Biomedical Engineering

Olin Hall of Engineering 500
(213) 740-7237
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Email: bmedept@usc.edu
Web: www.usc.edu/dept/biomed

Chair: David Z. D'Argenio, Ph.D.

Faculty
Dwight C. and Hildagard E. Baum Chair in Biomedical Engineering: David Z. D'Argenio, Ph.D.

Professors: Michael O. Arbib, Ph.D. (*Computer Science, Neurobiology*); Michel Baudry, Ph.D. (*Natural Sciences and Mathematics*); George A. Bekey, Ph.D. (*Electrical Engineering, Computer Science and Speech Science*); Theodore W. Berger, Ph.D. (*Neurobiology*); Richard N. Bergman, Ph.D. (*Physiology and Biophysics*); Edward K. Blum, Ph.D. (*Mathematics, Computer Science*); David Z. D'Argenio, Ph.D.*; Robert E. Kalaba, Ph.D. (*Economics, Electrical Engineering*); Michael C.K. Khoo, Ph.D.; Richard Leahy, Ph.D. (*Electrical Engineering and Radiology*); Gerald E. Loeb, M.D.; Vasilis Z. Marmarelis, Ph.D. (*Electrical Engineering*); Chrysostomos Nikias, Ph.D. (*Electrical Engineering*); Dennis O'Leary, Ph.D. (*Otolaryngology, Physiology and Biophysics*); Prakash N. Shrivastava, Ph.D. (*Radiation Oncology*); Manbir Singh, Ph.D. (*Radiology*); Stanley M. Yamashiro, Ph.D. (*Electrical Engineering*)

Associate Professors: Peter S. Conti, M.D., Ph.D. (*Radiology)*; Sandra Howell, Ph.D. (*Biokinesiology and Physical Therapy*); Kwang-Jin Kim, Ph.D. (*Medicine and Physiology*); Jill McNitt-Gray, Ph.D. (*Exercise Science*); Armand R. Tanguay, Jr., Ph.D. (*Electrical Engineering*)

Assistant Professors: William R. Dougherty, M.D. (*Surgery*); Jean-Michel Maarek, Doc.Ing.; Bartlett W. Mel, Ph.D.

Research Professor: Gilbert A. Chauvet, Ph.D., M.D. (*Theoretical Biology, University of Angers, France*)

Research Associate Professor: Edward T. Chow, Ph.D. (*Radiology*)

Research Assistant Professors: Jim-Shih Liaw, Ph.D.; Wee Ling Wong, Ph.D.; Xiaping Xie, M.D.

Adjunct Professor: Joseph H. Schulman, Ph.D. (*Alfred E. Mann Foundation*)

Adjunct Associate Professors: Samuel E. Landsberger, Sc.D. (*Rancho Los Amigos Medical Center*); Robert V. Shannon, Ph.D. (*House Ear Institute*)

Adjunct Assistant Professor: Adrian A. Polliak, Ph.D. (*Rancho Los Amigos Medical Center*)

*Recipient of university-wide or school teaching award.

Degree Requirements

Bachelor of Science in Biomedical Engineering
The requirement for the degree is 128 units. A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within the Biomedical Engineering Department.

See common requirements for undergraduate degrees, page 458.

Technical electives are to be selected from an approved list available in the department office.

FIRST YEAR, FIRST SEMESTER		UNITS
BME 101	Introduction to Biomedical Engineering	3
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
General education		4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
MATH 126	Calculus II	4
General education*	Social Issues	4
WRIT 140*	Writing and Critical Reasoning	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
BISC 110L	Introduction to Biology I	4
CSCI 101L	Fundamentals of Computer Programming	3
MATH 226	Calculus III	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		15

SECOND YEAR, SECOND SEMESTER		UNITS
BISC 112L	Introduction to Biology II	4
BME 210	Biomedical Computer Simulation Methods	3

MATH 245	Mathematics of Physics and Engineering I	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		15

THIRD YEAR, FIRST SEMESTER		UNITS
CHEM 322aL	Organic Chemistry	4
EE 202L	Linear Circuits	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
WRIT 340	Advanced Writing	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
BME 302L	Medical Electronics	4
BME 403	Physiological Systems	3
CHEM 322bL	Organic Chemistry	4
EE 301a	Introduction to Linear Circuits	3
General education		4
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
BME 405L	Senior Projects: Measurements and Instrumentation, or	
BME 406L	Senior Projects: Software Systems	4
BME 423	Statistical Methods in Biomedical Engineering	3
Electives	technical	7
General education		4
		18

FOURTH YEAR, SECOND SEMESTER		UNITS
BISC 311L	Molecular Biology	4
BME 402	Control and Communication in the Nervous System	3
Elective	technical	4
General education		4
		15

*Taken concurrently.

**Satisfies general education Category III.

Bachelor of Science in Biomedical Engineering (Biochemical Engineering)

The requirement for the degree is 128 units. A grade point average of C (2.0) is required in all course work taken at USC as well as all courses taken within the Department of Biomedical Engineering. See general education and additional common requirements for undergraduate degrees, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
BME 101	Introduction to Biomedical Engineering	3
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
MATH 125	Calculus I	4
General education		4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
MATH 126	Calculus II	4
General education*	Social Issues	4
WRIT 140*	Writing and Critical Reasoning	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
BISC 110L	Introduction to Biology I	4
CSCI 101L	Fundamentals of Computer Programming	3
MATH 226	Calculus III	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		15

SECOND YEAR, SECOND SEMESTER		UNITS
BISC 112L	Introduction to Biology II	4
BME 210	Biomedical Computer Simulation Methods	3
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		15

THIRD YEAR, FIRST SEMESTER		UNITS
BISC 311	Molecular Biology	4
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 322aL	Organic Chemistry	4
WRIT 340	Advanced Writing	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
BME 403	Physiological Systems	3
BME 410	Introduction to Biomaterials	3
BISC 316L	Biochemistry and Cell Biology	4
CHE 350	Introduction to Separation Processes, or	
CHEM 322bL	Organic Chemistry	4
General education		4
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
BISC 300L	Introduction to Microbiology	4
BME 423	Statistical Methods in Biomedical Engineering	3
EE 202L	Linear Circuits	4
General education		4
		15

FOURTH YEAR, SECOND SEMESTER		UNITS
BISC 478	Computational Genome Analysis	4
BME 302L	Medical Electronics	4
BME 402	Control and Communication in the Nervous System	3
CHE 489	Biochemical Engineering	3
General education		4
		18

*Taken concurrently.

**Satisfies general education Category III.

Combined Major in Biomedical/Electrical Engineering

The requirement for the degree is 136 units. A grade point average of C (2.0) is required in all course work taken at USC, as well as all courses taken within the Department of Biomedical Engineering. Both majors are listed on the diploma upon completion of the dual major curriculum. See common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
BME 101	Introduction to Biomedical Engineering	3
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
CSCI 101L	Fundamentals of Computer Programming	3
EE 101	Introduction to Digital Logic	3
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		18

SECOND YEAR, FIRST SEMESTER		UNITS
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
EE102L	Introduction to Digital Circuits	2
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
BME 210	Biomedical Computer Simulation Methods	3
EE 202L	Linear Circuits	4
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
		15

THIRD YEAR, FIRST SEMESTER		UNITS
BISC 110L	Introduction to Biology I	4
BME 425	Basics of Biomedical Imaging	3
CHEM 322aL	Organic Chemistry	4
EE 301a	Introduction to Linear Systems	3
EE 338	Physical Electronics	3
		17

THIRD YEAR, SECOND SEMESTER		UNITS
BISC 112L	Introduction to Biology II	4
BME 403	Physiological Systems	3
EE 357	Basic Organization of Computer Systems	3
MATH 445	Mathematics of Physics and Engineering II	4
General education		4
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
BME 423	Statistical Methods in Biomedical Engineering	3
EE 330	Electromagnetics I	3
EE 348L	Electronic Circuits I	4
General education		4
Electives	technical	3
		17

FOURTH YEAR, SECOND SEMESTER		UNITS
BISC 311	Molecular Biology	4
BME 402	Control and Communication in the Nervous System	3
EE 454L	Introduction to Systems Design Using Microprocessors, or	
EE 478L	Digital Electronic Circuit Design	4
WRIT 340	Advanced Writing	3
General education		4
		18

*Taken concurrently.

**Satisfies general education Category III.

Combined Major in Biomedical/Mechanical Engineering

The requirement for the degree is 133 units. A cumulative GPA 2.0 (C average) is required for all courses taken at USC, as well as all courses taken within the Biomedical Engineering Department. Technical electives are to be selected from the approved list available from the department.

FIRST YEAR, FIRST SEMESTER		UNITS
BME 101	Introduction to Biomedical Engineering	3
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education	Social Issues	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
CSCI 101L	Fundamentals of Computer Programming	3
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		15

SECOND YEAR, FIRST SEMESTER		UNITS
AME 203	Mechanics I	5
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		17

SECOND YEAR, SECOND SEMESTER		UNITS
AME 205	Mechanics II	5
BME 210	Biomedical Computer Simulation Methods	3
MATH 245	Mathematics of Physics and Engineering I	4
General education		4
		16

THIRD YEAR, FIRST SEMESTER		UNITS
BISC 110L	Introduction to Biology I	4
CE 309	Fluid Mechanics	3
CHEM 322aL	Organic Chemistry	4
MASC 310	Mechanical Behavior of Materials	3
General education		4
		18

THIRD YEAR, SECOND SEMESTER		UNITS
BISC 112L	Introduction to Biology II	4
BME 403	Physiological Systems	3
EE 202L	Linear Circuits	4
ME 451	Linear Control Systems	3
General education		4
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
BME 404	Biomechanics	3
BME 405L	Senior Projects: Measurements and Instrumentation, or	
BME 406L	Senior Projects: Software Systems	4
BME 423	Statistical Methods in Biomedical Engineering	3
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
WRIT 340	Advanced Writing	3
		17

FOURTH YEAR, SECOND SEMESTER		UNITS
AME 308	Computer-Aided Analyses for Aero-Mechanical Design	3
BISC 311	Molecular Biology	4
BME 402	Control and Communication in the Nervous System	3
ME 310	Engineering Thermodynamics I	3
General education		4
		17

*Taken concurrently.

**Satisfies general education Category III.

Master of Science in Biomedical Engineering

The Master of Science in Biomedical Engineering is awarded in strict conformity with the general requirements of the School of Engineering. At least 28 approved units must be satisfactorily completed, of which at least 19 units must be at the 500 level or above, and four units must be thesis BME 594abz.

The master's program provides students with a broad background, linking physiology with engineering science, necessary for entering interdisciplinary careers in medical technology or pursuing further graduate studies in a related field.

REQUIRED COURSES		UNITS
BME 501	Advanced Topics in Biomedical Systems	4
BME 502	Advanced Studies of the Nervous System	4
BME 513	Signal and Systems Analysis	3
BME 523	Measurement and Processing of Biological Signals	3
BME 533	Seminar in Bioengineering	1
BME 591a	Mathematical Biophysics	3
BME 594abz	Master's Thesis	2-2-0
Electives	technical	6
		28

Master of Science in Biomedical Engineering (Biomedical Imaging and Telemedicine)

The entrance requirements are identical to those for admission to the existing program for the Master of Science in Biomedical Engineering. Completion of the Master of Science in Biomedical Engineering (Biomedical Imaging and Telemedicine) requires that at least 29 approved units must be satisfactorily completed of which at least 19 units must be at the 500 level or above.

REQUIRED COURSES		UNITS
BME 423	Statistical Methods in Biomedical Engineering	3
BME 425	Basics of Biomedical Imaging	3
BME 501	Advanced Topics in Biomedical Systems	4
BME 513	Signal and Systems Analysis	3
BME 525	Advanced Biomedical Imaging	4
BME 527	Introduction to Teleradiology and Multimedia Technology	3
BME 528	Medical Diagnostics, Therapeutics and Informatics Applications	3
EE 469	Introduction to Digital Media Engineering	3
EE 569	Introduction to Digital Image Processing	3
		29

Doctor of Philosophy in Biomedical Engineering

The objective of the Doctor of Philosophy is to produce independent investigators who can make original scholarly contributions and apply advanced engineering concepts and techniques to the understanding and solution of biomedical problems. This program is intended to prepare the student for a career in academic research and teaching, or as an independent investigator in industrial or government laboratories.

The requirements listed are special to this department and must be read in conjunction with the general requirements of the Graduate School.

This program is designed to be normally completed in four years of full-time work beyond the Bachelor of Science degree (including summers). The first two years are devoted primarily to formal course work and the last two to research. In view of the flexible program, each student is assigned an advisor who will guide him or her in the selection of courses. At the end of the first year of graduate study the student must pass a screening examination. During the second year he or she is required to make a tentative major field selection (e.g., biomedical imaging, signal processing, neural engineering) and pass a qualifying examination. In accordance with the requirements of the Graduate School, at least 60 units of credit beyond the Bachelor of Science degree are required, with a minimum grade point average of 3.0. Students are required to take BME 533, the graduate biomedical engineering seminar course, for three semesters during their studies.

Requirements for Admission

Bachelor of Science degree in engineering or a natural science, and satisfactory scores on the Graduate Record Examinations. Undergraduate work should include a basic course in biology, physics, organic chemistry, bio-

chemistry, differential equations, and digital computation. Students lacking any of these will be required to make up the deficiency during the first two years of graduate work.

Students who have completed all requirements for the Master of Science degree offered in this department may apply for admission to the Ph.D. program. In this case, all courses taken in the M.S. program may be applied toward the requirements of the doctoral degree.

Screening Examination
At the end of the first year of graduate study, all students must take a screening examination to determine whether or not they will be allowed to continue in the Doctor of Philosophy program. Those who fail will be dropped from the program, although they may be permitted to complete the additional requirements necessary to obtain the Master of Science degree.

Guidance Committee
During the third semester, the student must make a tentative major field selection as described above and form a guidance committee. The latter administers the qualifying examination.

Qualifying Examinations
The qualifying examinations will normally be taken during the fourth semester of full-time academic study. The examinations require the preparation of a comprehensive written research proposal which presents a research question, critically reviews the pertinent literature and outlines the proposed experimental, analytical and computational procedures required to answer the question. The proposal must be defended in an oral examination.

Courses of Instruction

BIOMEDICAL ENGINEERING (BME)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

101 Introduction to Biomedical Engineering (3, Fa) Historical development and survey of major areas comprising biomedical engineering: theoretical neurobiology and systems physiology, biomedical instrumentation, artificial organ and prosthetic devices, biomedical computer applications.

110 Technological Applications in Biomedical Engineering (2) Presentation of biomedical technology and applications: instrumentation for cardiorespiratory diagnosis and management; hemodialysis technology; instrumentation for nerve function evaluation; medical lasers, medical imaging modalities. *Prerequisite:* BME 101.

210 Biomedical Computer Simulation Methods (3, Sp) Computational methods for simulation of circulatory, respiratory, pharmacokinetic, and neural models. Quadrature, differential equations, systems of linear equations, simulation languages, experimental statistics. (Duplicates credit in former BME 210*a*.) *Prerequisite:* CSCI 101*L*; *corequisite:* MATH 245.

302L Medical Electronics (4, Sp) Electronic design and measurements for medical applications. Use of integrated circuits, biopotential measurements, static and dynamic calibration of physiological transducers. *Prerequisite:* EE 202.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

402 Control and Communication in the Nervous System (3, Sp) An introduction to the structural and functional elements common to nervous systems, with emphasis on cellular dynamics, interneuronal communication, sensory and effector systems. *Prerequisite:* BISC 110*L*; MATH 245.

403 Physiological Systems (3, Sp) A thorough bioengineering treatment of the physiological properties of various mammalian organ systems: e.g., cardiovascular, respiratory, renal, and musculoskeletal. *Prerequisite:* BISC 110*L*; MATH 245.

404 Biomechanics (3, Fa) Mechanical properties of biological tissues and fluid transport in physiological systems: blood rheology; biovisco-elastic solids and fluids; gas flow and mixing; prosthesis design. *Prerequisite:* PHYS 152*L*, MATH 245, ME 201.

405L Senior Projects: Measurements and Instrumentation (4, Fa) Application of instrumentation and measurement techniques to biomedical engineering projects involving measurement, replacement or augmentation of biomedical systems. *Prerequisite:* BME 210, EE 202*L*.

406L Senior Projects: Software Systems (4, Fa) Software projects employing engineering, mathematical, and computational principles; applications include sensory and motor processing. (Duplicates credit in former BME 210*b*.) *Prerequisite:* BME 210.

410 Introduction to Biomaterials (3, Sp) Application of principles of physical chemistry, biochemistry, and materials engineering to biomedical problems, e.g., materials selection and design for implants of vital organs, etc.

414 Rehabilitation Engineering (3, Fa) An introduction to rehabilitation technology: limb and spinal orthoses; limb prostheses; functional electrical stimulation; sensory aids. *Recommended preparation:* ME 201 or ME 203.

423 Statistical Methods in Biomedical Engineering (3, Fa) Applications of parametric and non-parametric tests, analysis of variance, linear regression, time-series analysis, and autoregressive modeling, with biomedical applications to statistical analysis of biomedical data.

425 Basics of Biomedical Imaging (3, Fa) Basic scientific principles of various biomedical imaging modalities including nuclear magnetic resonance, X-ray computed tomography, single photon and positron emission tomography, ultrasonic imaging and biomagnetism. *Prerequisite:* PHYS 153*L*.

489 Biochemical Engineering (3, Sp) (Enroll in CHE 489)

490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

499 Special Topics (2-4, max 8) Current trends and developments in the field of biomedical engineering.

501 Advanced Topics in Biomedical Systems (4, Sp) Advanced topics in selected biomedical systems: cardiopulmonary, neuromuscular, renal and endocrine. (Duplicates credit in former BME 503*ab*.)

502 Advanced Studies of the Nervous System (4, Sp) Advanced topics on the structure and function of the nervous system examined from the viewpoint of computational systems science. (Duplicates credit in former BME 512.)

513 Signal and Systems Analysis (3, Fa) Classification; representation; statistical analysis; orthogonal expansions; least-squares estimation; harmonic analysis; Fourier, Laplace, and Z transforms; the linear system; filtering; modeling and simulation; linear control theory. *Prerequisite:* departmental approval.

523 Measurement and Processing of Biological Signals (3, Sp) Acquisition, analysis, and display of biological data using digital computers; laboratory applications of digital signal processing and real time analysis. *Prerequisite:* BME 513.

525 Advanced Biomedical Imaging (4, Sp) Advanced scientific and engineering principles of biomedical imaging including magnetic resonance, X-ray computed tomography, single photon and positron emission tomography, magnetoencephalography and electroencephalography. *Prerequisite:* departmental approval.

527 Introduction to Teleradiology and Multimedia Technology (3, Sp) The hardware, software and networking needs of multimedia technology with emphasis on user interface, communication, and storage and retrieval of radiological images will be discussed. *Prerequisite:* departmental approval.

528 Medical Diagnostics, Therapeutics and Informatics Applications (3, Sp) Clinical applications of biomedical imaging in decision making for diagnosis or therapy of patients with emphasis on clinical informatics including objective image evaluation techniques. *Prerequisite:* departmental approval.

533 Seminar in Bioengineering (1, max 3, Fa) Graded CR/NC.

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

591ab Mathematical Biophysics (a: 3, Fa; b: 3, Sp) Formulation of biological problems in mathematical terms. Analytical and computational solution of the relevant equations.

594abz Master's Thesis (2-2-0) Credit on acceptance of thesis. Graded IP/CR/NC.

599 Special Topics (2-4, max 9) Current trends and developments in the field of biomedical engineering.

605abL Experimental Projects in Biomedical Engineering (3-3, FaSp) Application of modern instrumentation and data processing techniques to the experimental study of selected biosystems. Laboratory. (Duplicates credit in former BME 519*L*.) *Prerequisite:* departmental approval.

680 Modeling and Simulation of Physiological Systems (3, Sp) Mathematical theories and computation techniques for modeling physiological systems, with emphasis on cardiorespiratory, metabolic-endocrine, and neuronal functions. *Prerequisite:* departmental approval.

686 Introduction to Biomedical Research (3, Fa) The nature of scientific research in bioengineering; scientific method; observation and interpretation; variation and error. Critical analysis of original literature and formulation of research problems. *Prerequisite:* departmental approval.

790 Research (1-12) Research applicable to the doctorate. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Chemical Engineering

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Chair: Muhammad Sahimi, Ph.D.

Faculty

John Robert Fluor Chair in Chemical Engineering: Ronald Salovey, Ph.D.* (*Materials Science*)

Robert E. Vivian Chair in Energy Resources: Theodore T. Tsotsis, Ph.D.

Professors: Iraj Ershaghi, Ph.D. (*Petroleum Engineering*); Florian Mansfeld, Ph.D. (*Materials Science*); Muhammad Sahimi, Ph.D.; Yanis C. Yortsos, Ph.D. (*Petroleum Engineering*)

Associate Professors: Wenji Victor Chang, Ph.D.; Katherine S. Shing, Ph.D.*

Assistant Professor: Ching-An Peng, Ph.D.

Adjunct Professor: Ronald G. Minet, Ph.D.

Adjunct Assistant Professor: Ian Webster, Sc.D.

Lecturers: Sidney Goodman, M.S.; M. Kezirian, Ph.D.; Eric Wagner, Ph.D.; K.W. Won, Ph.D.

Emeritus Professors: Elmer L. Dougherty, Ph.D. (*Petroleum Engineering*); Lyman L. Handy, Ph.D. (*Petroleum Engineering*); Ferdinand A. Kroger, Ph.D. (*Materials Science*); Frank J. Lockhart, Ph.D., P.E.*; James M. Whelan, Ph.D. (*Electrical Engineering and Materials Science*)

*Recipient of university-wide or school teaching award.

Chemical Engineering Honor Society: Omega Chi Epsilon

Degree Requirements

Program Goals

To ensure that our graduates are adequately prepared for graduate studies in various related fields (health science professions, environmental, biochemical and biomedical engineering, for example) and for employment in the great variety of industries in California, the neighboring states and the Pacific Rim, the Chemical Engineering Department has set the following educational goals:

(1) To provide each student with a rigorous but flexible education in mathematics, basic science and engineering science. These foundational courses will facilitate lifelong learning and professional adaptability in today's rapidly changing, highly technological society.

(2) To provide the students with a flexible selection of areas of emphasis within the major field of chemical engineering and to equip the students with the ability to apply their scientific knowledge and engineering skills to the creative solution of problems.

(3) To ensure that students develop effective oral and writing communications skills and the ability to function well within groups.

(4) To impart to the students the importance of both personal and professional development.

Bachelor of Science in Chemical Engineering

The requirement for the degree is 132 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in the Department of Chemical Engineering. See the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CHE 120	Introduction to Chemical Engineering	3
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
CSCI 101L	Fundamentals of Computer Programming	3
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		18

SECOND YEAR, FIRST SEMESTER		UNITS
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 300L	Analytical Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		16

SECOND YEAR, SECOND SEMESTER		UNITS
CE 205	Statics	2
CHE 350	Introduction to Separation Processes	4
CHEM 322aL	Organic Chemistry	4
MATH 245	Mathematics of Physics and Engineering I	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CHE 442	Chemical Reactor Analysis	4
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHEM 430a	Physical Chemistry	4
Elective***	technical	3
General education		4
		18

THIRD YEAR, SECOND SEMESTER		UNITS
CHE 443	Unit Operations of Chemical Engineering	4
CHE 476	Chemical Engineering Materials	3
EE 438L	Processing for Microelectronics	3
WRIT 340	Advanced Writing	3
General education		4
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
CHE 444L	Chemical Engineering Laboratory	4
CHE 445	Molecular Transport Processes	4
CHE 485	Computer-Aided Chemical Process Design	3
General education		4
		15

FOURTH YEAR, SECOND SEMESTER		UNITS
CHE 460L	Chemical Process Dynamics and Control	4
CHE 480	Chemical Process and Plant Design	3
ISE 460 BUAD 301	Engineering Economy, or Technical Entrepreneurship	3
Elective***	technical	4
		14

*Taken concurrently.

**Satisfies general education category III.

***Restricted technical electives (7 units)
CHEM 322bL (4) or CHEM 430b (4) and an upper division CHE course (3).

Bachelor of Science in Chemical Engineering (Biochemical Engineering)

The requirement for the degree is 136 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in the Departments of Chemical Engineering, Biomedical Engineering and Biological Sciences. See also the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
CHE 120	Introduction to Chemical Engineering	3
CSCI 101L	Fundamentals of Computer Programming	3
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		18

SECOND YEAR, FIRST SEMESTER		UNITS
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 300L	Analytical Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		16

SECOND YEAR, SECOND SEMESTER		UNITS
BISC 311	Molecular Biology	4
CHE 350	Introduction to Separation Processes	4
CHEM 322aL	Organic Chemistry	4
MATH 245	Mathematics of Physics and Engineering I	4
		16

THIRD YEAR, FIRST SEMESTER		UNITS
BISC 300L	Introduction to Microbiology	4
BISC 316L	Biochemistry and Cell Biology	4
CHE 442	Chemical Reactor Analysis	4
CHEM 430a	Physical Chemistry	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
CHE 443	Unit Operations of Chemical Engineering	4
ISE 460 BUAD 301	Engineering Economy, or Technical Entrepreneurship	3
WRIT 340	Advanced Writing	3
General education		8
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
BISC 403	Advanced Molecular Biology: Eukaryotes	4
CHE 444L	Chemical Engineering Laboratory	4
CHE 445	Molecular Transport Processes	4
CHE 489	Biochemical Engineering	3
Elective***	technical	3
		18

FOURTH YEAR, SECOND SEMESTER		UNITS
BME 410	Introduction to Biomaterials	3
CHE 460L	Chemical Process Dynamics and Control	4
CHE 480	Chemical Process and Plant Design	3
General education		8
		18

*Taken concurrently.

**Satisfies general education Category III.

***Restricted technical elective (3 units)
CHE 485 or CHE 405.

Bachelor of Science in Chemical Engineering (Petroleum Engineering)

The requirement for the degree is 136 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in the Department of Chemical Engineering. See the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CHE 120	Introduction to Chemical Engineering	3
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
CSCI 101L	Fundamentals of Computer Programming	3
		18

SECOND YEAR, FIRST SEMESTER		UNITS
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 300L	Analytical Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		16

SECOND YEAR, SECOND SEMESTER		UNITS
CHE 350	Introduction to Separation Processes	4
CHEM 322aL	Organic Chemistry	4
MATH 245	Mathematics of Physics and Engineering I	4
General education		4
		16

THIRD YEAR, FIRST SEMESTER		UNITS
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 442	Chemical Reactor Analysis	4
CHEM 430a	Physical Chemistry	4
PTE 461	Formation Evaluation	3
PTE 463L	Introduction to Transplant Processes in Porous Media	3
		17

THIRD YEAR, SECOND SEMESTER		UNITS
CHE 443	Unit Operations of Chemical Engineering	4
CHE 476	Chemical Engineering Materials	3
ISE 460 / BUAD 301	Engineering Economy, or Technical Entrepreneurship	3
WRIT 340	Advanced Writing	3
General education		4
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
CHE 444L	Chemical Engineering Laboratory	4
CHE 445	Molecular Transport Processes	4
CHE 485	Computer-Aided Chemical Process Design	3
PTE 465L	Drilling Technology and Subsurface Methods	3
General education		4
		18

FOURTH YEAR, SECOND SEMESTER		UNITS
CHE 460L	Chemical Process Dynamics and Control	4
CHE 480	Chemical Process and Plant Design	3
PTE 464L	Petroleum Reservoir Engineering	3
General education		4
Elective***	technical	4
		18

*Taken concurrently.

**Satisfies general education category III.

***Restricted technical electives (4 units) CHEM 322bL (4) or CHEM 430b (4).

Bachelor of Science in Chemical Engineering (Environmental Engineering)

The requirement for the degree is 135 units. A grade point average of C (2.0) or higher is required in all upper division courses taken in the Department of Chemical Engineering and the Department of Civil Engineering. See also the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL / CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CHE 120	Introduction to Chemical Engineering	3
CHEM 105bL / CHEM 115bL	General Chemistry, or Advanced General Chemistry	4
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		15

SECOND YEAR, FIRST SEMESTER		UNITS
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 300L	Analytical Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		16

SECOND YEAR, SECOND SEMESTER		UNITS
CHE 350	Introduction to Separation Processes	4
CHEM 322aL	Organic Chemistry	4
CSCI 101L	Fundamentals of Computer Programming	3
MATH 245	Mathematics of Physics and Engineering I	4
WRIT 340	Advanced Writing	3
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CE 453	Water Quality Control	3
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 442	Chemical Reactor Analysis	4
CHEM 430a	Physical Chemistry	4
PTE 463L	Introduction to Transport Processes in Porous Media	3
		17

THIRD YEAR, SECOND SEMESTER		UNITS
CHE 443	Unit Operations of Chemical Engineering	4
CHE 476	Chemical Engineering Materials	3
Air Pollution elective***		3
General education		8
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 463L	Water Chemistry and Analysis	3
CHE 444L	Chemical Engineering Laboratory	4
CHE 445	Molecular Transport Processes	4
CHE 485	Computer-Aided Chemical Process Design	3
ISE 460 BUAD 301	Engineering Economy, or Technical Entrepreneurship	3
		17

FOURTH YEAR, SECOND SEMESTER		UNITS
CHE 460L	Chemical Process Dynamics and Control	4
CHE 480	Chemical Process and Plant Design	3
CHE 486	Design of Environmentally Benign Process Plants	3
General education		8
		18

*Taken concurrently.

**Satisfies general education Category III.

***Restricted Air Pollution elective (3 units) ENE 428L or ENE 429.

Bachelor of Science in Chemical Engineering (Polymer Science)

The requirement for the degree is 136 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in the Departments of Chemical Engineering, Biomedical Engineering, Materials Science and Electrical Engineering. See also requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		
CHE 120	Introduction to Chemical Engineering	3
CHEM 105bL CHEM 115bl	General Chemistry, or Advanced General Chemistry	4
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
CSCI 101L	Fundamentals of Computer Programming	3
		18

SECOND YEAR, FIRST SEMESTER		
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 300L	Analytical Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		16

SECOND YEAR, SECOND SEMESTER		
CHE 350	Introduction to Separation Processes	4
CHEM 322aL	Organic Chemistry	4
MATH 245	Mathematics of Physics and Engineering	4
General education		4
		16

THIRD YEAR, FIRST SEMESTER		
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 442	Chemical Reactor Analysis	4
CHE 472	Polymer Science and Engineering	3
CHEM 430a	Physical Chemistry	4
General education		4
		18

THIRD YEAR, SECOND SEMESTER		
CHE 443	Unit Operations of Chemical Engineering	4
CHE 474L	Polymer Science and Engineering Laboratory	3
CHE 476	Chemical Engineering Materials	3
WRIT 340	Advanced Writing	3
Technical Elective***		4
		17

FOURTH YEAR, FIRST SEMESTER		
CHE 444L	Chemical Engineering Laboratory	4
CHE 445	Molecular Transport Processes	4
CHE 477	Computer Assisted Polymer Engineering and Manufacturing	3
CHE 485	Computer-Aided Chemical Process Design	3
General education		4
		18

FOURTH YEAR, SECOND SEMESTER		
CHE 460L	Chemical Process Dynamics and Control	4
CHE 480	Chemical Process and Plant Design	3
ISE	Engineering Economy	3
Materials Elective ****		3
General Education		4
		17

* Taken concurrently

** Satisfies general education Category III

*** Restricted technical electives (4 units): CHEM 322bL (4) or CHEM 430b (4)

**** Restricted materials elective (3 units): EE 438L (3) or BME 410 (3) or CHE 475 (3) or CHE 478 (3).

Bachelor of Science in Chemical Engineering (Manufacturing Engineering)

If a student chooses six courses (9 to 18 units) from a prescribed program, he or she may graduate with the special designation Area of Emphasis in Manufacturing Engineering on the transcript. Details are given under Manufacturing Engineering on page 524.

Master of Science in Chemical Engineering

The Master of Science in Chemical Engineering is awarded in strict conformity with the general requirements of the USC School of Engineering with the exception that the minimum unit requirement is 28. Two semesters of registration in CHE 550 are required.

Engineer in Chemical Engineering

Requirements for the Engineer in Chemical Engineering are the same as set forth in the general requirements. See general requirements for graduate degrees.

Doctor of Philosophy

The Doctor of Philosophy (Ph.D.) degree in chemical engineering is awarded in conformity with the general requirements of the Graduate School. See general requirements for graduate degrees.

Departmental Policies and Requirements
In addition to the general requirements for the Ph.D. described in this catalogue, candidates in chemical engineering are required to demonstrate proficiency in the following fields: thermodynamics, fluid flow, heat and mass transfer and chemical engineering kinetics. Four semesters of registration in CHE 550 are required of all students. More detailed statements of the departmental requirements may be found in a brochure available upon request from the Department of Chemical Engineering.

Chemical Engineering Three-Two Plan
A special curriculum is available for obtaining a Bachelor of Science degree in chemical engineering and a Bachelor of Science or Bachelor of Arts degree in a letters, arts and sciences major in five years. For further information see departmental advisors.

Similar programs are available in cooperation with certain liberal arts colleges. Such programs are particularly suited for obtaining a Bachelor of Science in Chemistry at the liberal arts college and a Bachelor of Science in Chemical Engineering at USC.

Courses of Instruction

CHEMICAL ENGINEERING (CHE)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

120 Introduction to Chemical Engineering (3, Sp) Problem-solving techniques in chemical engineering using graphics and computers. Mass and heat balances. *Corequisite:* MATH 125; CHEM 105*aL* or CHEM 115*aL*.

330 Chemical Engineering Thermodynamics (4, Fa) Elements of chemical engineering thermodynamics, including generalized correlations of properties of materials, phase behavior, physical and chemical equilibria. *Corequisite:* MATH 226.

350 Introduction to Separation Processes (4, Sp) Use of equilibrium phase relations and principles of material and energy balance for design, operation, and optimization of separation procedures such as distillation, absorption, etc. *Prerequisite:* CHE 330; CHEM 105*bL* or CHEM 115*bL*.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

405 Applications of Probability and Statistics for Chemical Engineers (3, Fa) Principles of probability and statistics, random variables and random functions. Application to chemical engineering problems, including process design, process safety, heterogeneous materials and processes. *Prerequisite:* MATH 245.

410 Introduction to Biomaterials (3, Sp) (Enroll in BME 410)

426 Rubber Technology (2, Fa) Natural and synthetic rubbers - their testing, compounding, chemistry, and uses; developments in the rubber industry. *Recommended preparation:* CHEM 322*bL*.

442 Chemical Reactor Analysis (4, Fa) Basic concepts of chemical kinetics and chemical reactor design. *Prerequisite:* MATH 245.

443 Unit Operations of Chemical Engineering (4, Sp) Fluid flow, heat transfer, and other topics in unit operations. *Corequisite:* CHE 350.

444L Chemical Engineering Laboratory (4, Fa) Resolution of chemical engineering problems which require original planning, observations, and data. Field trips to chemical plants. Written and oral reports. *Prerequisite:* CHE 350 and CHE 443.

445 Molecular Transport Processes (4, Fa) Phenomenological rate laws, field equations, and elementary molecular kinetic-theory aspects of heat, mass, and momentum transport. Applications to technological and natural systems. *Prerequisite:* CHE 443, MATH 245.

460L Chemical Process Dynamics and Control (4, Sp) Simulation, stability, and automatic control of chemical processes. Open and closed loop control schemes and introduction to optimal control theory. Computer implementation and laboratory application. *Prerequisite:* CHE 120; *corequisite:* MATH 245.

461 Formation Evaluation (3) (Enroll in PTE 461)

462 Economic, Risk and Formation Productivity Analysis (4) (Enroll in PTE 462)

463L Introduction to Transport Processes in Porous Media (3) (Enroll in PTE 463)

464L Petroleum Reservoir Engineering (3) (Enroll in PTE 464*L*)

465L Drilling Technology and Subsurface Methods (3) (Enroll in PTE 465*L*)

472 Polymer Science and Engineering (3, Fa) The preparation, characterization, and properties of synthetic polymers. An interdisciplinary approach to polymers as materials. *Recommended preparation:* CHEM 322*aL*.

474L Polymer Science and Engineering Laboratory (3, Sp) Experimental methods for the preparation, characterization, and properties of synthetic polymers. *Recommended preparation:* CHE 472.

475 Physical Properties of Polymers (3, Fa) Theoretical methods and semi-empirical correlations for estimating mechanical, thermodynamic, transport, optical, and electrical properties of polymer solutions, melts, networks, glasses, polymer blends and semi-crystalline polymers. *Recommended preparation:* CHE 472 and CHEM 430*a*.

476 Chemical Engineering Materials (3, Sp) Chemical and physical properties of solid materials used by chemical engineers, including polymers, metals, and ceramics. Materials design for industrial applications. *Prerequisite:* CHEM 322*aL*.

477 Computer Assisted Polymer Engineering and Manufacturing I (3, Fa) Estimation of physical, mechanical, chemical and processing properties of thermal plastics. Major molding processes. Mold flow simulation and residual stresses analysis. Case studies. *Prerequisite:* junior class standing or departmental approval.

478 Plastic Materials (3, Sp) An examination of classes of polymers of commercial interest; structure, physical properties, and applications; comparison among materials. *Recommended preparation:* CHE 472.

480 Chemical Process and Plant Design (3, Sp) Applications of unit operations, thermodynamics, kinetics, and economic balance; energy conservation in heat exchanger networks and in sequencing of separational devices. Safety aspects. *Prerequisite:* senior standing.

485 Computer-Aided Chemical Process Design (3, Fa) Use and optimization of modern computer software for chemical process design. *Prerequisite:* CHE 442, CHE 443.

486 Design of Environmentally Benign Process Plants (3, Sp) Chemical Process Plants interact with the environment as an integrated system. This course discusses design procedures to minimize unwanted effluents to air, water and solid wastes. *Corequisite:* CHE 480 or CHE 485.

489 Biochemical Engineering (3, Fa) Application of chemical engineering principles to biological and biochemical processes and materials. Design of biochemical reactors and of processes for separation and purification of biological products. *Prerequisite:* CHE 330, BISC 311 or departmental approval.

490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

499 Special Topics (2-4, max 8) Course content to be selected each semester from recent developments in chemical engineering and related fields.

501 Modeling and Analysis of Chemical Engineering Systems (3) Application of mathematics to problems in chemical engineering; mathematical modeling, differential and integral equations, linear systems analysis and stability, asymptotic and numerical methods. *Recommended preparation:* CHE 445, MATH 245.

521 Corrosion Science (3) (Enroll in MASC 521)

522 Corrosion Technology (3) (Enroll in MASC 522)

523 Principles of Electrochemical Engineering (3) (Enroll in MASC 523)

530 Thermodynamics for Chemical Engineers (3) Application of thermodynamics to chemical engineering systems. *Recommended preparation:* CHE 330.

531 Enhanced Oil Recovery (3) (Enroll in PTE 531)

532 Vapor-Liquid Equilibrium (3) Thermodynamics of phase relations; prediction and correlation of phase behavior. *Prerequisite:* CHE 330.

540 Viscous Flow (3) Fluid mechanical problem of interest to chemical engineers involving laminar flows of incompressible fluids, viscous-dominated creeping flows, and motion of bubbles and drops. *Prerequisite:* CE 309 or AE 309 or CHE 443.

541 Mass Transfer (3) Fundamentals of mass transfer within a single phase and between phases; applications to separation processes. *Recommended preparation:* CHE 445.

542 Chemical Engineering Kinetics (3) Reaction kinetics applied to problems of engineering design and operation. *Recommended preparation:* CHE 442.

544 Heat Transmission (3) Principles of conduction, radiation, and convection of heat; application to chemical and related industries. *Recommended preparation:* CHE 330, CHE 445.

550 Seminars in Chemical Engineering (1/2, max 2, FaSp) Seminars to cover recent developments in the field of chemical engineering given by invited speakers. Master's students must register for 2 semesters; Ph.D. students must register for 4 semesters. Graded CR/NC. *Recommended preparation:* graduate standing.

582 Fluid Flow and Transport Processes in Porous Media (3) (Enroll in PTE 582)

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

594abz Master's Thesis (2-2-0) Credit on acceptance of thesis. Graded IP/CR/NC.

596 Chemical Reactions in the Atmosphere (3) (Enroll in ENE 596)

599 Special Topics (2-4, max 9) Course content will be selected each semester to reflect current trends and developments in the field of chemical engineering.

690 Directed Research (1-4) Laboratory study of specific problems by candidates for the degree Engineer in Chemical Engineering. Graded CR/NC.

790 Research (1-12) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Civil Engineering

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Chair: L. Carter Wellford, Ph.D.

Faculty

Fred Champion Chair in Civil Engineering: Masanobu Shinozuka, Ph.D., P.E.

Professors: Ahmed Abdel-Ghaffar, Ph.D.; James C. Anderson, Ph.D.*; Jean-Pierre Bardet, Ph.D.; George V. Chilingar, Ph.D. (*Petroleum Engineering*); Joseph S. Devinny, Ph.D. (*Environmental Engineering*); Jiin-Jen Lee, Ph.D., P.E. (*Environmental Engineering*)*; Geoffrey R. Martin, Ph.D.; Sami F. Masri, Ph.D. (*Mechanical Engineering*); Massoud Pirbazari, Ph.D. (*Environmental Engineering, Associate Director of Environmental Engineering*); Costas Synolakis, Ph.D. (*Aerospace Engineering*); Mihailo Trifunac, Ph.D.; Firdaus E. Udwadia, Ph.D. (*Mechanical Engineering*); L. Carter Wellford, Ph.D. (*Chair*) (*Director of Environmental Engineering*); Hung Leung Wong, Ph.D.*; Teh Fu Yen, Ph.D. (*Environmental Engineering*)

Associate Professors: Ronald C. Henry, Ph.D. (*Environmental Engineering*); Vincent W. Lee, Ph.D.; Najmedin Meshkati, Ph.D., C.P.E. (*Industrial and Systems Engineering*); James Moore, Ph.D. (*Policy, Planning, and Development*)

Assistant Professors: Erik A. Johnson, Ph.D.; Constantinos Sioutas, Sc.D.; Yan Xiao, Ph.D., P.E.

Adjunct Professor: Gregg E. Brandow, Jr., Ph.D., P.E.

Research Associate Professors: Craig Taylor, Ph.D.; Maria I. Todorovska, Ph.D.

Research Assistant Professors: John A. Kuprenas, D.Eng., P.E.; Robert Nigbor, Ph.D., P.E.

Senior Lecturer: Henry M. Koffman, P.E.

Emeritus Professors: Mihran S. Agbabian, Ph.D., P.E.; Edwin L. Bidwell, Ph.D.; Kenneth C. Reynolds, Sc.D.; Paul Seide, Ph.D.; Victor I. Weingarten, Ph.D.

*Recipient of university-wide or school teaching award.

Chi Epsilon Civil Engineering Honor Society

Chi Epsilon is dedicated to the purpose of maintaining and promoting the status of civil engineering as a profession. Chi Epsilon was organized to recognize the characteristics of the individual civil engineer deemed to be fundamental to the successful pursuit of an engineering career and to aid in the development of those characteristics in the civil engineering student. To contribute to the improvement of the profession, Chi Epsilon fosters the development and exercise of sound traits of character and technical ability among civil engineers.

Chi Epsilon is based on broad principles of scholarship, character, practicality and sociability. Civil engineering students who rank in the upper one-third of the junior or senior class are eligible for membership. These qualifications will make one eligible but not necessarily acceptable. Each member must be well skilled in all four of the basic principles.

Degree Requirements

Program Goals
The undergraduate programs in Civil Engineering have the following objectives:

(1) Graduates will be expected to compete effectively in the world of rapid technological changes and to become leading professionals in industrial, academic or government institutions.

(2) Graduates will be prepared to tailor their undergraduate studies to embark into the engineering professions, to continue their graduate studies in engineering, or to enter related areas like computer science, business, law, medicine or a field of their choice and interest.

(3) Graduates will have demonstrated proficiency in mathematics, science and engineering principles to effectively solve engineering problems encountered in work and practice.

(4) Graduates will have the ability to communicate both verbally and orally and to function effectively as individuals or as members of multidisciplinary teams in a world of rapid technological changes and global competition.

(5) Graduates will understand the importance of contemporary engineering issues, decisions, risks and benefits in a global social and environmental context, as well as the importance of personal and professional ethics.

(6) Graduates will have the knowledge to design all or part of a system to meet the required constraints and specifications, as well as the desired economic, social, ethical, political, environmental and other necessary considerations.

(7) Graduates will have the capacity to conduct and design laboratory experiments with available state-of-the-art equipment, and to use the techniques to analyze and interpret the experimental data.

Bachelor of Science in Civil Engineering (131 Unit Program)
A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within the Department of Civil Engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225, 309 and 325. See also common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 106	Design and Planning of Civil Engineering Systems	2
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		18

FIRST YEAR, SECOND SEMESTER		UNITS
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computational Methods in Civil Engineering	2
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		13

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		8
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
MATH 245	Mathematics of Physics and Engineering I	4
ME 310	Engineering Thermodynamics I	3
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry, or	
GEOL 305	Introduction to Engineering Geology, or	
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
CE 471	Principles of Transportation Engineering	3
EE 202L EE 326L	Linear Circuits, or Essentials of Electrical Engineering	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
CE 334L	Mechanical Behavior of Materials	3
CE 402	Computer Methods in Engineering	3
ISE 460	Engineering Economy	3
Kernel course***		3
Elective	civil engineering	3
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 453	Water Quality Control	3
CE 467	Geotechnical Engineering	4
Kernel course***		3
Elective	civil engineering	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 451	Water Resources Engineering	4
CE 480	Structural Systems Design	3
Kernel course***		3
WRIT 340	Advanced Writing	3
General education		4
		17

*Taken concurrently.

**Satisfies a general education requirement for Category III.

***Kernels must be selected from the following list of design courses: CE 409abL, CE 429, CE 456, CE 457, CE 465, CE 476 or CE 478.

The Department of Civil Engineering must approve all curricula leading to a degree; please note this includes transfer credit and units for courses waived for subject credit only, which have been approved through the Degree Progress Department.

Bachelor of Science in Civil Engineering (with Construction Engineering Emphasis)

A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within the Department of Civil Engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225, 309 and 325. See also common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 106	Design and Planning of Civil Engineering Systems	2
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		18

FIRST YEAR, SECOND SEMESTER		UNITS
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computational Methods in Civil Engineering	2
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		13

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
CE 460	Construction Engineering	3
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		17

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
MATH 245	Mathematics of Physics and Engineering I	4
ME 310	Engineering Thermodynamics I	3
GEOL 305	Introduction to Engineering Geology	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
CE 471	Principles of Transportation Engineering	3
EE 202L EE 326L	Linear Circuits, or Essentials of Electrical Engineering	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
CE 334L	Mechanical Behavior of Materials	3
CE 462	Construction Methods and Equipment	3
ISE 460	Engineering Economy	3
Kernel course***		3
General education		4
		16

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 409aL	Computer Aided Design	3
CE 412	Contracts and Specifications	3
CE 461	General Construction Estimating	3
CE 467L	Geotechnical Engineering	4
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 451	Water Resources Engineering	4
CE 480	Structural Systems Design	3
Kernel course***		3
WRIT 340	Advanced Writing	3
General education		4
		17

*Taken concurrently.

**Satisfies a general education requirement for Category III.

***Kernels must be selected from the following list of design courses: CE 456, CE 457, CE 465, CE 466, CE 476, CE 478. Students must select one course from CE 456, CE 457, CE 478.

The Department of Civil Engineering must approve all curricula leading to a degree; please note this includes transfer credit and units for courses waived for subject credit only, which have been approved through the Degree Progress Department.

Bachelor of Science in Civil Engineering (with Structural Engineering Emphasis)
A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within the Department of Civil Engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225, 309 and 325. See also common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 106	Design and Planning of Civil Engineering Systems	2
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		18

FIRST YEAR, SECOND SEMESTER		UNITS
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computational Methods in Civil Engineering	2
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		13

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		8
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
MATH 245	Mathematics of Physics and Engineering I	4
ME 310	Engineering Thermodynamics I	3
GEOL 305	Introduction to Engineering Geology	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
CE 456	Design of Steel Structures	3
EE 202L EE 326L	Linear Circuits, or Essentials of Electrical Engineering	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
CE 334L	Mechanical Behavior of Materials	3
CE 402	Computer Methods in Engineering	3
CE 457	Reinforced Concrete Design	3
CE 458	Theory of Structures II	3
ISE 460	Engineering Economy	3
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 409aL	Computer Aided Design	3
CE 460	Construction Engineering	3
CE 467L	Geotechnical Engineering	4
CE 478	Timber and Masonry Design	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 451	Water Resources Engineering	4
CE 459	Introduction to Structural Dynamics	3
CE 480	Structural Systems Design	3
WRIT 340	Advanced Writing	3
General education		4
		17

*Taken concurrently.

**Satisfies a general education requirement for Category III.

The Department of Civil Engineering must approve all curricula leading to a degree; please note this includes transfer credit and units for courses waived for subject credit only, which have been approved through the Degree Progress Department.

Bachelor of Science in Civil Engineering (with Water Resources Engineering Emphasis)

A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within the Department of Civil Engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225, 309 and 325. See also common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 106	Design and Planning of Civil Engineering Systems	2
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
General education*	Social Issues	4
WRIT 140*	Writing and Critical Reasoning	4
		18

FIRST YEAR, SECOND SEMESTER		UNITS
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computational Methods in Civil Engineering	2
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		13

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		8
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
MATH 245	Mathematics of Physics and Engineering I	4
ME 310	Engineering Thermodynamics I	3
CHEM 105bL CHEM 115bL	General Chemistry, or Advanced General Chemistry, or	
GEOL 305	Introduction to Engineering Geology, or	
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
CE 471	Principles of Transportation Engineering	3
EE 202L EE 326L	Linear Circuits, or Essentials of Electrical Engineering	4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
CE 334L	Mechanical Behavior of Materials	3
CE 402	Computer Methods in Engineering	3
ISE 460	Engineering Economy	3
Kernel course***		3
Elective	civil engineering	3
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 453	Water Quality Control	3
CE 467	Geotechnical Engineering	4
Kernel course***		3
Elective	civil engineering	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 451	Water Resources Engineering	4
CE 485	Wastewater Treatment Design	3
Kernel course***		3
WRIT 340	Advanced Writing	3
General education		4
		17

*Taken concurrently.

**Satisfies a general education requirement for Category III.

***Kernels must be selected from the following list of design courses: CE 465, CE 466 or CE 476.

The Department of Civil Engineering must approve all curricula leading to a degree; please note this includes transfer credit and units for courses waived for subject credit only, which have been approved through the Degree Progress Department.

Bachelor of Science in Civil Engineering (Building Science) (135 Unit Program)

A cumulative grade point average of C (2.0) is required in all courses taken at USC, as well as for all courses taken within the Department of Civil Engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225, 309 and 325. See also the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 106	Design and Planning of Civil Engineering Systems	2
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		18

FIRST YEAR, SECOND SEMESTER		UNITS
ARCH 114	Introduction to Modern Architecture	2
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computer Methods in Civil Engineering	2
MATH 126	Calculus II	4
PHYS 151L****	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		15

SECOND YEAR, FIRST SEMESTER		UNITS
ARCH 205aL**	Building Science I	4
CE 205	Statics	2
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
ARCH 205bL**	Building Science I	4
CE 225	Mechanics of Deformable Bodies	3
GEOL 305	Introduction to Engineering Geology, or	
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
MATH 245	Mathematics of Physics and Engineering I	4
ME 310	Engineering Thermodynamics I	3
		18

THIRD YEAR, FIRST SEMESTER		UNITS
ARCH 305aL**	Building Science II	4
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
CE 456	Design of Steel Structures	3
		16

THIRD YEAR, SECOND SEMESTER		UNITS
ARCH 214b	History and Theory II	4
ARCH 305bL**	Building Science II	4
CE 334L	Mechanical Behavior of Materials	3
CE 457	Reinforced Concrete Design	3
General education		4
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
ARCH 405aL**	Building Science III	4
CE 408	Risk Analysis in Civil Engineering	3
CE 467L	Geotechnical Engineering	4
Civil Engineering elective***		3
General education		4
		18

FOURTH YEAR, SECOND SEMESTER		UNITS
ARCH 405bL**	Building Science III	4
CE 458	Theory of Structures II	3
WRIT 340	Advanced Writing	3
General education		4
		14

*Taken concurrently.

**The School of Architecture requires a minimum grade of C in ARCH 205ab, 305ab and 405ab in order to continue in the building science design sequence.

***The Civil Engineering elective must be selected from the following courses: CE 409a, CE 451, CE 453, CE 460, and CE 471.

****Satisfies general education Category III.

Bachelor of Science in Civil Engineering (Environmental Engineering) (130 Unit Program)

A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within the Department of Civil Engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225, 309 and 325. See also common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 110	Introduction to Environmental Engineering	4
MATH 125	Calculus I	4
General education*	Social Issues	4
WRIT 140*	Writing and Critical Reasoning	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 210L	Introduction to Environmental Engineering Microbiology	3
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		17

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
ENE 400	Environmental Engineering Principles	3

MATH 245	Mathematics of Physics and Engineering I	4
ME 310	Engineering Thermodynamics	3
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics, or	
GEOL 305	Introduction to Engineering Geology	4
		17

THIRD YEAR, FIRST SEMESTER		UNITS
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
WRIT 340	Advanced Writing	3
General education		4
		16

THIRD YEAR, SECOND SEMESTER		UNITS
CE 334L	Mechanical Behavior of Materials	3
CE 451	Water Resources Engineering	4
CE 453	Water Quality Control	3
ISE 460	Engineering Economy	3
Kernel course***		3
		16

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 467L	Geotechnical Engineering	4
Kernel course***		3
General education		4
		14

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 463L	Water Chemistry and Analysis	3
CE 485	Wastewater Treatment Design	3
ENE 428L	Air Pollution Fundamentals	3
General education		4
Kernel course***		3
		16

*Taken concurrently.

**Satisfies a general education requirement for Category III.

***Kernels must be selected from the following design courses: CE 409aL, CE 443, CE 457, CE 465, CE 466, CE 476, CE 484 and ENE 429.

Bachelor of Science in Environmental Engineering (132 Unit Program)

A cumulative scholarship average of C (2.0) is required for all courses taken at USC as well as for all courses taken in the Civil Engineering Department. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, 225 and ENE 410. See also common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 110	Introduction to Environmental Engineering	4
MATH 125	Calculus I	4
General education*	Social Issues	4
WRIT 140*	Writing and Critical Reasoning	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 210L	Introduction to Environmental Engineering Microbiology	3
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		17

SECOND YEAR, FIRST SEMESTER		UNITS
BISC 110L	Introduction to Biology I	4
CE 205	Statics	2
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
ENE 400	Environmental Engineering Principles	3
ENE 410	Environmental Fluid Mechanics	3
MATH 245	Mathematics of Physics and Engineering	4
General education		4
		14

THIRD YEAR, FIRST SEMESTER		UNITS
CE 453	Water Quality Control	3
CHEM 322aL	Organic Chemistry	4
ENE 428	Air Pollution Fundamentals	3
WRIT 340	Advanced Writing	3
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 451	Water Resources Engineering	4
GEOL 305Lx	Introduction to Engineering Geology	4
Kernel course***		3
General education		4
		18

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 465	Water Supply and Sewerage System Design	3
CE 484	Water Treatment Design	3
CHE 330	Chemical Engineering Thermodynamics	4
ISE 460	Engineering Economy	3
PTE 463L	Introduction to Transport Processes in Porous Media	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 463L	Water Chemistry and Analysis	3
CE 485	Wastewater Treatment Design	3
ENE 429	Air Pollution Control	3
ENE 486	Solid and Hazardous Waste Engineering	3
General education		4
		16

*Taken concurrently.

**Satisfies a general education requirement for Category III.

***One Kernel course must be selected from the following list of courses: CE 402, CE 409aL, CE 443 and CHE 442.

Minor in Environmental Engineering

See listing on page 514.

Minor in Construction Planning and Management

This program covers the most current theories and practice of construction planning and management. The program provides a valuable adjunct credential to professional school students pursuing careers in business administration, public administration, environmental studies, and other areas; and a unique opportunity for professional focus to students in the USC College of Letters, Arts and Sciences.

Construction activities are complex. In contemporary society, effective planning and management of these activities requires specialized knowledge of the technical, economic and policy environment. This program couples the knowledge of how construction activities are organized with a broader understanding of the urban system in which construction projects are embedded. With the exception of statistics, all of the required courses are within the Department of Civil Engineering and the USC School of Policy, Planning, and Development.

Any USC undergraduate who has completed the equivalent of two full-time semesters in good standing is eligible to pursue the minor program. This minor program is rigorous enough to serve as an introductory credential for students subsequently electing to pursue advanced studies in development, urban planning, construction management or allied fields.

Courses required

Seven courses consisting of at least 23 units are required for the minor.

Statistics

Students must complete an advisor approved course in statistics. Candidate courses include ECON 317, EE 364, ISE 220, PPD 404, PSYCH 274, SOCI 314 and similar courses. The statistics course must be at least three units.

CORE COURSES		UNITS
CE 460	Construction Engineering	3
CE 461	General Construction Estimating	3
CE 462	Construction Methods and Equipment	3
PLDV 361	Property, Governance and the Environment	4
PLDV 402	Urban Economic Analysis Planning	4
		17

ELECTIVES (SELECT ONE)		UNITS
CE 404	Fundamentals of Law for Engineers	3
CE 412	Contracts and Specifications	3
CE 472	Construction Labor Management	3
PLDV 403	Advanced Finance and Investment for Planning and Development	4

Advisement is provided by the Department of Civil Engineering. Students will normally complete statistics before enrolling in CE 461 but can be permitted to complete statistics as a corequisite subject to advisor approval. CE 460 is a prerequisite for CE 461 for the purposes of the minor. Students are also advised to take CE 460 before taking CE 462. Students electing PLDV 403 must have completed PLDV 402.

Master of Science in Civil Engineering

The Master of Science in Civil Engineering is awarded in strict conformity with the general requirements of the USC School of Engineering. A student may receive the Master of Science in Civil Engineering with a special option by specializing in one of the following courses of study: construction; earthquake engineering; nuclear engineering; ocean engineering; soil mechanics and foundations; structural engineering; structural mechanics; environmental engineering; transportation engineering; and water resources. Students specializing in the transportation option must include in their program either four units of CE 590 or 594ab.

A general Master of Science in Civil Engineering without special designation is also given. Specific course requirements (at least 15 units) for a degree with special designation may be secured by request from the Department of Civil Engineering.

A student who wishes to pursue the Master of Science in Civil Engineering without special designation and who has an interest in public works may take a selected sequence of 12 units in the USC School of Policy, Planning, and Development. For further information, see the USC School of Policy, Planning, and Development section, page 721.

Master of Science in Applied Mechanics

Students possessing a bachelor's degree in aerospace engineering, civil engineering, mechanical engineering, mathematics, or physics may work toward the Master of Science in Applied Mechanics. A student may be required to satisfy certain deficiencies considered prerequisite to the listed courses.

The Master of Science in Applied Mechanics is awarded in strict conformity with the general requirements for the Master of Science in Civil Engineering, except as modified by the following specific requirements. Students must include in their course work: (1) CE 507, 508, 525ab, 541b and AE 510ab; (2) at least six units of electives from the following: CE 541a, 542, 543; (3) other electives may be substituted on approval of department chair; (4) there is no thesis option.

Master of Science in Environmental Engineering

Students with a bachelor's degree in engineering or science may work toward the Master of Science in Environmental Engineering. Students with degrees in fields other than engineering or science may be admitted on the recommendation of a program advisor and program director. Selection of courses will be determined through consultation with a program advisor to provide a maximum of training in the student's area of interest in environmental problems.

Master of Construction Management

Students possessing a bachelor's degree and with sufficient training in capital management and statistics may pursue the Master of Construction Management. This is an interdisciplinary degree program offered jointly by the Department of Civil Engineering and the USC School of Policy, Planning, and Development. A single application is made to the Department of Civil Engineering. The purpose of the Master of

Construction Management program is to educate and train multidisciplinary professionals to understand and execute the broad array of technical and non-technical activities associated with construction management. The program provides special attention to the function of the constructor in real estate development. The core of the program is drawn from the MSCE program in construction engineering and management, and from the USC School of Policy, Planning, and Development's Master of Real Estate Development program. Additional elective courses are available in both units, in the Department of Industrial and Systems Engineering, the USC School of Architecture, and the USC Marshall School of Business. In addition, students may seek advisor approval for electives from other units in the university, such as the USC School of Policy, Planning, and Development, the USC Law School or the USC Davis School of Gerontology.

CORE CURRICULUM		UNITS
CE 501	Functions of the Constructor	3
CE 556ab	Project Cost Estimating and Control	3-3
CE 502	Construction Accounting and Finance, or	
GSBA 510	Accounting Concepts and Financial Reporting	3
RED 542	Finance of Real Estate Development	4
RED 509	Market Analysis for Real Estate	4
ARCH 511L	Seminar: Building Systems	4
Additional advisor approved technical and advanced electives		9
Total minimum units		33

The minimum requirement for the Master of Construction Management degree is 33 units. At least three elective courses totaling at least 9 units are required for this degree. These may be taken from the Department of Civil Engineering, other engineering departments, the USC School of Policy, Planning, and Development, the USC School of Architecture, the USC Davis School of Gerontology, the USC Law School or the USC Marshall School of Business subject to advisor approval. Admission to some classes requires advanced prerequisites and is subject to availability and approval of the instructor.

General Requirements
Residence and Course Load
The normal time required for earning the Master of Construction Management is three semesters, including one summer semester beginning in July and continuing through the spring semester ending in May. Students are expected to participate in extracurricular activities associated with the Master of Construction Management program, including the speaker series and field trips. A candidate must complete the last four semester units of course work at USC.

Students who wish a leave of absence for a semester or longer must request it from the chairman of the Civil Engineering Department in writing. Such leaves may be granted for up to one year.

For further information see the USC School of Policy, Planning, and Development section, page 738.

Master of Engineering in Computer-Aided Engineering
The Master of Engineering program educates and trains multidisciplinary professionals in the use of computational techniques in the planning, design and management of engineering projects. The emphasized computer-aided engineering subjects are modeling, simulation, visualization, optimization, artificial intelligence and advanced design, documentation, manufacturing and information management. The program provides the graduate with advanced education in a particular engineering subject area, associated with aerospace, civil or mechanical engineering. This advanced engineering education is coupled with an intensive concentration in computational procedures appropriate for that subject area. The program also includes substantial project work to provide a background in the application of CAE techniques in real world situations.

For further information see the listing under Computer-Aided Engineering, page 494.

Engineer in Civil Engineering
Requirements for the Engineer in Civil Engineering are the same as set forth in the general requirements.

Doctor of Philosophy in Civil Engineering and Doctor of Philosophy in Engineering (Environmental Engineering)
The Doctor of Philosophy with a major in civil engineering and the Doctor of Philosophy with a major in engineering (environmental engineering) are also offered. See general requirements for graduate degrees.

Areas of specialization for Doctor of Philosophy level students are: structural engineering, structural mechanics, earthquake engineering, coastal engineering, water resources engineering, soil mechanics and foundation engineering, hydrology, hydrodynamics and transportation.

Certificate in Computer-Aided Engineering
The Certificate in Computer-Aided Engineering is a limited version of the Master of Engineering in Computer-Aided Engineering program. It is designed to focus on providing an understanding of the overall field of computer-aided engineering. It includes a course covering the necessary computer science skills and a course introducing basic simulation techniques used in computer-aided engineering. In addition, the certificate provides knowledge in the use of CAE tools in a project environment. See the listing under Computer-Aided Engineering, page 495.

Graduate Certificate in Transportation Systems
The graduate certificate in Transportation Systems is an interdisciplinary program administered by the Department of Civil Engineering. The certificate program allows students to specialize in transportation applications, while simultaneously receiving a degree in their home department. The certificate in Transportation Systems combines elements of transportation engineering with transportation policy, planning and project management. The program is especially appropriate for students intending to pursue careers as developers of transportation technologies, or as implementors of technologies within government agencies.

Students electing the certificate program apply to the Department of Civil Engineering. Course prerequisites for the program are:

(1) one course in statistics or uncertainty, equivalent to ISE 225, PPD 404 or CE 408;

(2) one course in engineering economy, equivalent to ISE 460;

(3) one course in microeconomics, equivalent to ECON 203; and

(4) one course in a high level programming language, such as C or Fortran.

These prerequisites may be satisfied after enrollment in the certificate program by taking the indicated courses or their equivalent. Graduate students cannot receive credit for courses numbered below 400. Detailed admissions requirements are published by the Department of Civil Engineering.

Qualified students holding a bachelor's degree also have the option of enrolling in the certificate program without receiving a separate graduate degree.

The curriculum consists of five graduate courses for a total of 17 units.

CERTIFICATE REQUIREMENTS		UNITS
CE 519	Transportation Engineering	3
CE 585	Traffic Engineering and Control	3
ISE 515	Institutional and Policy Issues in Transportation	3
PLUS 580	Urban Transportation Planning and Management	4
PLUS 581	Institutional and Policy Issues in Transportation	4

Courses of Instruction

CIVIL ENGINEERING (CE)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

105L Surveying for Civil Engineering (2, Fa) Plane surveying, measurement of distances and angles, horizontal curves, surveying computations. Laboratory.

106 Design and Planning of Civil Engineering Systems (2) History of civil engineering; introduction to the synthesis and design of systems dependent upon civil engineering technology; the structuring, modeling, and simulation of such systems.

107 Introduction to Civil Engineering Graphics (3, FaSp) Graphic communication and drawing; use of instruments, lettering, dimensioning, and detailing of engineering drawing; free-hand sketching, drafting, and modeling.

108 Introduction to Computer Methods in Civil Engineering (2, Fa) Computer programming, organization of problems for computational solution, flow charts, programming; numerical methods; analysis and solution of civil engineering problems.

110 Introduction to Environmental Engineering (4, Fa) Basic concepts of environmental engineering. Local and global environmental pollution; scientific, social, legal and political aspects of environmental issues; air/water/land pollution and control technologies.

203 Spatial Organization of Society (4, FaSp) (Enroll in PLDV 203)

205 Statics (2) Statics of particles and rigid bodies; equivalent force systems; distributed forces; applications to trusses, frames, machines, beams, and cables; friction; moments of inertia. (Duplicates credit in CE 227 or CE 228.) *Corequisite:* PHYS 151*L*.

210L Introduction to Environmental Engineering Microbiology (3, Sp) Principles of environmental microbiology; waterborne pathogens; microorganisms and air pollution; microorganisms in soil; water pollution microbiology; biodegradation of hazardous chemicals; eutrophication. *Prerequisite:* CE 110; *corequisite:* CHEM 105*aL* or CHEM 115*aL*.

225 Mechanics of Deformable Bodies (3) Analysis of stress and strain; axial, flexural, and torsional behavior of slender bars; elastic deflections; combined stresses; introduction to elastic stability and energy methods. *Prerequisite:* CE 205.

306L Civil Engineering Measurement Systems (3) Mensuration and instrumentation for civil engineering practice. Cadastral, route, and construction surveying systems. Professional responsibility, managerial and supervisory controls for field surveying operations. *Prerequisite:* CE 105*L*.

309 Fluid Mechanics (3, FaSp) Fluid statics; relative velocity field; total acceleration; divergence theorem; conservation of mass, energy, and momentum applied to engineering problems in laminar and turbulent flow. *Prerequisite:* MATH 126; *corequisite:* CE 325.

325 Dynamics (3) Elements of vector algebra; dynamics of particles, systems of particles and rigid bodies; kinematics; momentum relations, energy methods; vibrations; Euler's equations of motion. *Prerequisite:* CE 205.

334L Mechanical Behavior of Materials (3, Sp) Measurement of stress and strain; tensile, impact, creep, and fatigue behavior; statistical methods, brittle fracture; properties of structural materials. *Prerequisite:* CE 225 or ME 204.

358 Theory of Structures I (3, Fa) Deformations and deflections of elastic systems; statically indeterminate beams, arches, and frames; secondary stresses. *Prerequisite:* CE 225.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

402 Computer Methods in Engineering (3, FaSp) Fundamentals of analog and digital computers; simulation of nonlinear physical systems; numerical analysis and solution of engineering problems. *Prerequisite:* CE 108 and MATH 245.

404 Fundamentals of Law for Engineers (3, Sp) Legal problems confronting the engineer in his professional environment and daily life. Survey of the legal system and how it operates.

406 Microcomputer Applications in Civil Engineering (3) Solution of civil engineering problems using microcomputers; frame analysis, beam and column design; common database problems, solution of large numerical problems using limited computer resources.

407 Analytical Mechanics (3) Principles of dynamics; Lagrange equations; Hamilton's principle; rigid body dynamics; gyroscopic motion; wave propagation; vibrations of multi-degree freedom systems. *Prerequisite:* CE 228.

408 Risk Analysis in Civil Engineering (3, Fa) Realization of nondeterministic problems in civil engineering; quantitative analysis of structural and system reliability; optimal design and design with specified risk.

409abL Computer Aided Design (3-3, FaSp) Applications of interactive computer graphics to design problems; automated drafting; 3-D graphic algorithms. Analysis of design process from information processing viewpoint. *Prerequisite:* CE 225.

412 Contracts and Specifications (3, Fa) Standards of construction practices. Contracting law, agency, venture arrangements, agreements, conveyance, liens, contingency negotiations, and arbitration.

428 Mechanics of Materials (3) Analysis of stress and deformation; equations of elasticity; bending of beams; elastic instability; torsion problems; introduction to plates and shells; elastic wave propagation; numerical methods. *Prerequisite:* CE 225.

429 Structural Concept Design Project (3) Synthesis of structural systems to meet strength and stiffness requirements; RFPs; structural behavior; concept generation; preliminary analysis; trade-off studies; evaluation criteria; project management. *Prerequisite:* AE 353 or CE 358.

443 Environmental Chemistry (3, FaSp) Chemistry of water, gas, liquid and solid wastes. Chemical principles applicable to environmental engineering. *Prerequisite:* CHEM 105*bL* or CHEM 115*bL*.

451 Water Resources Engineering (4, Sp) Discussion of broad perspective on control and utilization of water resources; hydrology, probability concept, economic study, hydraulic structures, multiple purpose water resources projects. *Prerequisite:* CE 309.

453 Water Quality Control (3, FaSp) Water quality criteria and fundamental of acceptability. Natural purification of surface waters. Processes employed in the treatment of waste waters for disposal or re-use. *Prerequisite:* CHEM 105*aL* or CHEM 115*aL* and CE 309.

456 Design of Steel Structures (3, Fa) Analysis and design of steel structures; beam-columns, plate girders, and frames; multistory design project. *Corequisite:* CE 358.

457 Reinforced Concrete Design (3, Sp) Strength and deformation of reinforced concrete; beams in flexure and shear; bond and development of bars; deflections; columns; slabs; footings; introduction to prestressed concrete. *Prerequisite:* CE 225.

458 Theory of Structures II (3, Sp) Matrix algebra; stiffness method; force method; computer analysis of planar structures. *Prerequisite:* CE 108 and CE 358 or AE 150 and AE 353.

459 Introduction to Structural Dynamics (3, Sp) Response of single and multiple degree of freedom systems to dynamic excitation; structural modeling and approximate solutions; introduction to earthquake resistant design. *Corequisite:* CE 458.

460 Construction Engineering (3) Introduction to the construction processes; estimating and bidding, construction administration, planning and scheduling, equipment and methods, labor relations, cost control systems, and safety.

461 General Construction Estimating (3) Theory of estimating. Quantity surveying; unit cost synthesis and analysis. Bid organization and preparation; competitive simulations and exercises. *Prerequisite:* departmental approval.

462 Construction Methods and Equipment (3) Current procedures in selected fields of construction; organization and planning; equipment economics; machinery.

463L Water Chemistry and Analysis (3, FaSp) Chemistry of water purification technology and water pollution control. Chemical processes in natural and engineering aquatic environments; physical/chemical and biological characterization of water and wastewater. *Prerequisite:* CE 453, CHEM 105*b* or CHEM 115*bL*.

464 Geotechnical Engineering (3) Fundamentals of soil mechanics and foundation engineering; soil classification, seepage, stress-strain behavior, shear strength, consolidation, design of retaining structures and foundations, and slope stability.

465 Water Supply and Sewerage System Design (3, Fa) Design of water supply systems, storm drains, sanitary sewers, and lift stations. *Prerequisite:* CE 453.

466 Design of Free-Surface Hydraulic Systems (3) Hydrological and hydraulic design for uniform and non-uniform flows, channel transition, sedimentation controls, design discharge for tributary watersheds, flood routing, flood detention, computer aided design. *Prerequisite:* CE 309.

467L Geotechnical Engineering (4, Fa) Fundamentals of geotechnical engineering; soil classification, seepage, stress-strain behavior, shear strength, consolidation, design of retaining structures and foundations, and slope stability. Soil testing. (Duplicates credit in CE 464 and CE 468.) *Prerequisite:* CE 225.

468L Experimental Soil Mechanics (3) Laboratory testing of soils and computer processing of experimental measurements, soil classification, compaction tests, permeability tests, unconfined compression, direct sheet, consolidation, triaxial tests. *Prerequisite:* CE 464.

471 Principles of Transportation Engineering (3, Fa) Planning, design, construction, maintenance, and operation of facilities for air, water, rail, and highway transit systems.

472 Construction Labor Management (3) Unionism in construction. Craft tradition, objectives, regulation, motivation, labor force economics, productivity, and technical change. Hiring systems, supervision of project labor operations, jurisdictional administration.

476 Design of Pressurized Hydraulic Systems (3) Application of hydraulic principles to the engineering design of hydraulic structure with pressurized flow, piping network, water hammer, surge suppression, pumps and turbines, manifold hydraulic design. *Prerequisite:* CE 309.

478 Timber and Masonry Design (3, Fa) Characteristics and properties of wood; beams, columns, trusses, connectors, and diaphragms. Properties of masonry, working stress and strength design, seismic design requirements.

480 Structural Systems Design (3, Sp) Evaluate, design and analyze buildings. Organize and perform calculations for vertical loads, wind loads, and seismic loads on building projects. *Prerequisite:* CE 456, CE 457, or CE 478.

484 Water Treatment Design (3) Predesign studies, precipitation softening, coagulation and flocculation, sedimentation, filtration, sludge handling, chlorination, chloramination, ozonation; plant hydraulics, flow measurement, pumps, instrumentation and control, tertiary treatment. *Prerequisite:* CE 453.

485 Wastewater Treatment Design (3) Process kinetics, mass balance, reactor design, pretreatment, clarification, chemical treatment, biological treatment (aerobic and anaerobic), disinfection, sludge treatment, nitrogen and phosophorus removal, carbon adsorption. *Prerequisite:* CE 453.

488 Computer Applications in Structural Analysis and Design (3) Application of existing computer programs to the analysis and design of complex structures.

490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

499 Special Topics (2-4, max 8) Course content to be selected each semester from recent developments in civil engineering and related fields.

501 Functions of the Constructor (3) Systems, processes, and constraints governing the initiation, direction, engineering, and delivery of major construction projects. Professional construction management, responsibilities, and practice.

502 Construction Accounting and Finance (3) Cost control, finance, and engineering economy for construction operations.

503 Microbiology for Environmental Engineers (3) Basic microbiology of water, air, and soil. Application of microbiology to the practice of environmental pollution control.

504 Solid Waste Management (3) Characterization, production, storage, collection, and transport of solid wastes; alternative disposal methods; design principles and environmental impact; management of radiological solid wastes.

505 Heavy Construction Operations and Methods (3, Sp) Methods and operations involved in constructing hardrock and soft ground tunnels, shafts, bridge piers in water, and design-construction of concrete formwork and shoring.

506 Heavy Construction Estimating (3) Methods engineering, work analysis and pricing for route construction. Grading, draining, paving, haul economy, plant-materials production, pipeline and bridge building. *Prerequisite:* CE 462.

507 Mechanics of Solids I (3,Fa) Analysis of stress and strain; constitutive equations for elastic materials; plane stress and strain; torsion; introduction to plates and shells; energy methods.

508 Mechanics of Solids II (3) Thermal stresses; introduction to elastic stability; yield criteria; constitutive equations for elastoplastic materials; elastoplastic stress analysis; viscoelasticity and creep. *Prerequisite:* CE 507 or CE 428.

509 Mechanics of Solids III (3) Advanced topics in mechanics of solids; complex variable methods for plane problems; three-dimensional problems; introduction to fracture mechanics. *Prerequisite:* CE 507.

510 Groundwater Management (3) Groundwater hydrology, aquifer testing technology, groundwater quality and contamination, geophysical method, well design and development, basin water balance, computer modeling, legal aspects, groundwater management system.

511 Flood Control Hydrology (3) Flood frequency, storm characteristics, net rain; surface drainage, peak discharge, flood runoff.

512ab Special Topics in Hydrology (3-3) *a:* Topics in the hydrology of groundwater and low flow. *b:* Topics in the hydrology of floods and surface drainage.

513L Instrumental Methods for Environmental Analysis (3) Advanced techniques in gas, water, liquid, and solid waste analysis; theoretical and experimental consideration of electrometric, photometric, manometric, and chromatographic techniques for measurements of environmental pollution. Lecture, 2 hours; laboratory, 3 hours. *Prerequisite:* CE 463*L*.

514ab Advanced Sanitary Engineering Design (3-3, FaSp) Design of water and waste treatment works. *Prerequisite:* CE 453.

516 Geohydrology (3) Principles of groundwater motion; acquifer characteristics, prospecting, practical engineering problems, well design, maintenance and rehabilitation; hydrodynamic dispersion, field testing essentials and procedures, groundwater quality, artificial recharge.

517 Industrial and Hazardous Waste Treatment and Disposal (3, 2 years, Sm) Physical, chemical, and biological treatment processes for industrial and hazardous wastes; pretreatment systems, biodegradation of toxic chemicals; groundwater and soil decontamination; biofilters for air decontamination. *Prerequisite:* CE 463*L*.

519 Transportation Engineering (3) Principles of analysis and planning. Characteristics of transportation systems. Urban and regional systems. Relationship between environment and transportation systems. Estimating the impact of decisions.

520ab Ocean and Coastal Engineering (3-3) Linear and nonlinear wave theories with engineering applications; wind waves; wave spectra; wave interactions with marine structures; ship mooring, harbor resonance; sediment transport; diffusion processes. *Corequisite:* AE 510*a*.

522 Groundwater Hydrologic Modeling (3) Simulation of groundwater hydrologic processes through mathematical, analog, and physical models.

523 Physical Processes of Environmental Engineering (3, Sp) Environmental reactor design, coagulation, flocculation, sedimentation, filtration, adsorption, solid waste management (drying, centrifugation, incineration), membrane processes, advanced water treatment; mathematical modeling of physical processes. *Prerequisite:* CE 463*L*.

525ab Engineering Analysis (3-3) Typical engineering problems discussed on a physical basis. Setup and solution of problems by means of the existing mathematical tools.

526 Hydraulic Structures (3) Technical and economic analysis of hydraulic structures for water power, irrigation, and flood control; masonry, earth and rock-fill dams, outlet works. *Prerequisite:* CE 466 and CE 476.

527 Advanced Hydraulic Design (3) Advanced design of hydraulic structures such as dams, chutes, energy dissipators, manifolds, and canals; applications to multiple purpose design; design for unsteady flow systems. *Prerequisite:* CE 526.

528 Seismic Analysis and Design of Reinforced Concrete Bridges (3) Fundamental concepts, methods and current codes used in the analysis and design of reinforced concrete bridge structures. Experimental and earthquake observations of bridge performance. *Prerequisite:* CE 457; *recommended preparation:* CE 538.

529ab Finite Element Analysis (3-3) Basic concepts; stiffness method; variational methods; displacement method; isoparametric formulation; plane stress and strain; plates and shells; dynamics; stability; nonlinear analysis, heat transfer; computer applications.

530 Nonlinear Mechanics (3) Nonlinear problems in structural dynamics; elastic-plastic response; approximate methods of nonlinear analysis; stability theory; stability of periodic nonlinear oscillations; Liapounov's method; nonlinear buckling problems.

531 Soil Mechanics (3) Soil formation; clay mineralogy; steady state seepage; mechanical coupling between interstitial water and soil skeleton; experimental soil behavior and its modeling with constitutive equations. *Prerequisite:* CE 464.

532 Principles of Foundation Engineering (3) Fundamental methods in foundation engineering; plastic collapse, limit equilibrium, bearing capacity, slope stability; soil-structure interaction; application of numerical methods, finite differences and finite elements. *Prerequisite:* CE 464.

533 Geotechnical Earthquake Engineering (3, Sp) Provides a design-oriented understanding of the "state-of-the-practice" of soil mechanics and foundation engineering aspects of earthquake engineering.

534 Design of Earth Structures (3, Sp) Designed to provide a thorough understanding of the analytical and design principles underlying the construction of a broad range of earth structures.

535ab Earthquake Engineering (3-3) Fundamentals of earthquake engineering; characteristics of earthquakes; seismicity; response of linear and nonlinear multidegree systems; basic concepts in earthquake-resistant design; foundation problems.

536 Structural Design for Dynamic Loads (3) Earthquake resistant design criteria with application to steel reinforced concrete and timber structures. Design of blast resistant structures and structures subject to impact loads. *Prerequisite:* CE 459 or CE 541*a*.

537 Advanced Reinforced Concrete (3) Behavior of reinforced concrete members in terms of strength and deformation; relationship between behavior and building code requirements.

538 Prestressed Concrete (3) Fundamental principles of prestressing by pre- and post-tensioning; elastic and time dependent losses; stress analysis and design of prestressed and precast concrete structures.

539 Advanced Steel Structures (3) Design of tubular members and plate girders; design for torsional and seismic loads; general flexural theory; introduction to plastic design; connections.

540 Limit Analysis of Structures (3) Plastic analysis and design of frames. Fundamental theorems of plastic analysis; general methods of plastic analysis, design requirements, minimum weight design theorems and applications, shakedown theorems.

541ab Dynamics of Structures (a: 3, Fa; b: 3, Sp) *a:* Forced vibrations of discrete MDOF systems; modal analysis; energy methods; analytical dynamics; vibration of continuous systems; wave propagation; computational techniques; application of commercial software tools. *b:* Continuous system responses; approximate methods; introduction to structural control; random vibration concepts; response of continuous systems to random excitation; nonlinear systems (geometric theory), (approximate methods). *Prerequisite:* CE 541*a*.

542 Theory of Plates (3) Theory of plate bending; rectangular and circular plates; anisotropic plates; energy methods; numerical methods; large deformations; sandwich plates. *Prerequisite:* CE 428 or CE 507.

543 Stability of Structures (3) Critical loads of columns, beams, thin-wall bars, plates, shells; stability of frames and trusses; effect of inelastic behavior of materials; effect of dynamic loading.

544 Theory of Shell Structures (3) General bending theory of shells; membrane theory; shells of revolution; numerical methods; dynamic response. *Prerequisite:* CE 428 or CE 507.

545ab Advanced Finite Element Method in Structural and Continuum Mechanics (3-3) *a:* Finite elements in nonlinear mechanics, elasticity, plasticity, viscoelasticity; advanced finite element applications in fracture mechanics, heat transfer, fluid mechanics; computational implementation of finite element method. *Prerequisite:* 529*a*. *b:* Mathematical aspects of the finite element method; correctness of discretizations for elliptic, parabolic, and hyperbolic equations; accuracy and convergence considerations; stability of time dependent algorithms. *Prerequisite:* CE 545*a*.

546 Structural Mechanics of Composite Materials (3) Applications and manufacturing of composites: anisotropic materials; laminated composite plates and shells; buckling and dynamics; strength and failure; interlaminar stresses; delamination; thermal properties; design considerations.

547 Engineering Rock Mechanics (3) Basic characteristics of rocks; mechanical behavior of rocks, deformation, strength, and rock fracture; engineering applications, mining, excavation, tunneling, drilling, blasting, cutting and slope stability. *Prerequisite:* CE 464.

548 Foundation Design (3) Design of foundations and earth retaining structures; subsurface investigation; selection of foundation types, footing, raft, piles and pier foundations, shoring, underpinning, retaining walls and abutments. *Prerequisite:* CE 464.

550 Computer-Aided Engineering (3, Fa) Basic concepts of computer-aided engineering. Modeling; simulation; visualization; optimization; artificial intelligence; manufacturing; information management. Organization and management of computer-aided engineering projects.

551 Computer-Aided Engineering Project (3, Sp) Computer-aided engineering in a project environment. Responding to RFPs; conceptual design; preliminary analysis; overall and detailed analysis and design; trade-off studies; project management; project presentation.

552 Managing and Financing Public Engineering Works (3) Tools for improving the efficiency and effectiveness of public engineering works, taking into account the political and policy context. Graduate standing. *Recommended preparation:* microeconomic theory.

553 Chemical and Biological Processes in Environmental Engineering (3) Chemistry of softening, coagulation, disinfection, oxidation, corrosion control, dry and wet combustion and ion exchange; aerobic and anaerobic processes and the ecology of liquid and solid waste treatment. *Prerequisite:* CE 453.

554 Risk and Reliability Analysis for Civil Infrastructure Systems (3, Sp) Elements of feasibility, reliability, and risk analysis of civil infrastructure systems, simulation, optimization, life-cycle cost, evaluation and decision making.

555 Underwater Structures (3) Loads on underwater structures; stress analysis of typical structural elements; buckling problems; dynamic response. *Prerequisite:* CE 507.

556ab Project Cost Estimating and Control (3-3, FaSp) Fundamental principles and practices of cost estimating, budgeting, and cost control of construction projects. Case studies and software exercises based on project data. Graduate standing in engineering, architecture, business or urban planning required.

557 Advanced Building Estimating (3) Processes in compiling a bid for construction of non-residential building.

558 International Construction and Engineering (3, FaSp) Business development and project management in international markets. Topics include marketing, planning, contracts and negotiations, procurement, logistics, personnel and financing. Construction operations in adverse environments. Graduate standing in engineering, architecture, business, or urban planning required.

559 Strategic Planning in Construction Engineering (3) Elements and techniques of strategic planning for construction engineering. Fundamentals of engineering as a service sector enterprise. Assessment of markets (including international issues), competitors, and technology. Aspects of overseas engineering business. Management of technology and the role of R&D. Emphasis on concepts. *Recommended preparation:* CE 502.

560 Simulation of Civil Infrastructure Systems Performance (3, Sp) Time/space and frequency/wave number domain analysis, spectral representation of wind, earthquake and other natural loads, FEM techniques for system response simulation.

562ab Hydromechanics (3-3) Analytical solution of civil engineering problems concerned with hydraulic flow; water hammer, free-surface flow, waves and see page flow; application of theory to research and design.

563 Chemistry and Biology of Natural Waters (3, 2 years, Fa) Chemical and biological limnology; cycles of carbon, nitrogen, phosphorous, sulfur, and other biologically-mediated chemical transformations; effect of pollution on biology and chemistry of natural waters. *Prerequisite:* CE 443 and CE 453.

564 Methods for Assessment and Protection of Environmental Quality (3, Sp) Natural ecosystems, technologies for control and remediation of air, water, and soil pollution; natural hazards and urban lifeline systems; Design For The Environment (DFE).

565 Wave Propagation in Solids (3) Elastic waves in infinite and semi-infinite regions; plates and bars; steady-state and transient scattering; dynamic stress concentration; viscoelastic and plastic bodies.

572 Construction Labor Management (2) Unionism in construction. Craft tradition, objectives, regulation, motivation, labor force economics, productivity, and technical change. Hiring systems, supervision of project labor operations, jurisdictional administration.

583 Design of Transportation Facilities (3) Planning, design, staging, construction, test, and maintenance of the public works and facilities for land, water, and air transportation. *Prerequisite:* CE 519, CE 457, or departmental approval.

585 Traffic Engineering and Control (3) Conceptual engineering geometric design, installation, and calibration of vehicular storage and traffic controls; safe flow optimization of vehicles on various thoroughfares. *Prerequisite:* CE 471, ISE 220.

586x Management for Engineers (4) (Enroll in ME 586*x*)

587 Transportation Energy Analysis (3) Energy consumption and socioeconomic impacts of past, present, and future transportation systems; analysis of alternatives between energy-intensive and low-cost transportation modes.

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

594abz Master's Thesis (2-2-0) Credit on acceptance of thesis. Graded IP/CR/NC.

599 Special Topics (2-4, max 9) Course content will be selected each semester to reflect current trends and developments in the field of civil engineering.

613 Advanced Topics in Environmental Chemistry (3) Kinetic examination of time-dependent phenomena with reference to processes of environmental control; electrokinetic properties and structure of clays; other topics related to water processes technology. *Prerequisite:* CE 443.

640 Advanced Theory of Elasticity (3) Curvilinear tensors; equations of nonlinear elasticity; elementary solutions; small deformations superimposed on large deformations; bifurcation of equilibrium states; nonlinear shell theory. *Prerequisite:* CE 507.

690 Directed Research (1-4, max 8) Laboratory study of specific problems by candidates for the degree Engineer in Civil Engineering. Graded CR/NC.

694abz Thesis (2-2-0) Required for the degree Engineer in Civil Engineering. Credit on acceptance of thesis. Graded IP/CR/NC.

790 Research (1-12) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Computer-Aided Engineering

Degree Requirements

Kaprielian Hall 210
(213) 740-0603
FAX: (213) 744-1426
Email: civileng@usc.edu

Master of Engineering in Computer-Aided Engineering

The Master of Engineering program educates and trains multidisciplinary professionals in the use of computational techniques in the planning, design and management of engineering projects. The computer-aided engineering tools which are emphasized are modeling, simulation, visualization, optimization, artificial intelligence and advanced design, documentation, manufacturing and information management. The program provides the graduate with a credential which represents the completion of advanced training in a particular engineering application area, coupled with an intensive concentration in computational procedures appropriate for that application area. The focus of the program is on advanced engineering design involving aerospace, civil and mechanical engineering systems. The program includes substantial project work designed to provide a background in the application of CAE techniques in real world situations. This program is not oriented to the engineering of electrical or computer systems. The USC School of Engineering, through the Department of Electrical Engineering, offers various programs which focus on computer-aided engineering techniques related to electrical and computer engineering projects.

The minimum requirement for the Master of Computer-Aided Engineering is 30 units. The curriculum has three segments: computer-aided engineering core, the discipline specific core and the computational electives.

Computer-Aided Engineering Core
Fifteen units are required, including courses emphasizing graduate level mathematics, basic computer science principles, an introduction to simulation, an overview of computer-aided engineering techniques, and computer-aided engineering projects. The core involves the choice of two simulation courses — CE 529a, which involves finite element analysis and a structural orientation, and AE 535a, which involves a fluid mechanics orientation.

The Master of Engineering program involves major design project work in the computer-aided engineering overview course, CE 550, and in the computer-aided engineering project course. Students have a choice of project courses. CE 551 is a generic course incorporating structural, fluid and thermal projects. AE 535b focuses entirely on fluid mechanics projects. Some students may wish to pursue specialized projects not covered in either of these courses. They may complete a specialized project by taking the AE, CE, ME 590 directed research courses through an appropriate advisor.

CAE CORE CURRICULUM		UNITS
AE 525b	Engineering Analysis, or	
CE 525b	Engineering Analysis, or	
ME 526	Engineering Analytical Methods	3
AE 535a	Introduction to Computational Fluid Mechanics, or	
CE 529a	Finite Element Analysis	3
CS 455x	Introduction to Programming Systems Design	3
CE 550	Computer-Aided Engineering	3
AE 535b	Introduction to Computational Fluid Mechanics, or	
CE 551	Computer-Aided Engineering Project, or	
AE 590	Directed Research*, or	
CE 590	Directed Research*, or	
ME 590	Directed Research*	3

*approved individual CAE project (project may be extended by 3 units by using one of the computational electives)

Discipline Specific Core
Six units are required involving advanced graduate level engineering courses. These courses are designed to focus on fundamental theory rather than design or computational techniques. All courses are to be taken from the same basic discipline, selected by the student. The possible basic disciplines include structural and solid mechanics, fluid mechanics, thermal analysis and combustion, geomechanics, and other areas of applied mechanics. The student is provided with a list of the acceptable courses in each discipline. In general, these lists include courses from the Departments of Mechanical, Civil and Aerospace Engineering.

Computational Electives
Nine units are required involving advanced graduate level engineering courses which focus on computational procedures. The student is provided with lists of acceptable computational electives. These electives are designed to cover the computational areas of geometric modeling, simulation, visualization, optimization, artificial intelligence and advanced design, documentation, manufacturing and information management. The student is permitted to spread electives over multiple computational areas.

Certificate in Computer-Aided Engineering
The Certificate in Computer-Aided Engineering provides students possessing a bachelor's degree in civil engineering, mechanical engineering or aerospace engineering, with a specialized education covering the use of computational techniques in the planning and design of engineering projects. This program is closely related to the Masters of Engineering in Computer-Aided Engineering program. For a student pursuing a master's degree in some other area, the certificate makes it possible to add, at a reasonable cost, a credential representing advanced training in computer-aided engineering.

The Certificate in Computer-Aided Engineering involves 12 units of course work.

PREREQUISITE	
CSCI 455x	Introduction to Programming Systems Design, or equivalent courses covering undergraduate computer science topics including programming principles, data structures and software engineering

CAE CORE CURRICULUM		UNITS
AE 535a	Introduction to Computational Fluid Mechanics, or	
CE 529a	Finite Element Analysis	3
CE 550	Computer-Aided Engineering	3
AE 535b	Introduction to Computational Fluid Mechanics, or	
CE 551	Computer-Aided Engineering Project	3

COMPUTATIONAL ELECTIVE
One course to be selected from a list of advanced courses covering the computational techniques most important in computer-aided engineering.

Computer Engineering

Undergraduate Degree

Email: eesystem@ceng.usc.edu

Program Goals
The undergraduate program in Computer Engineering and Computer Science has the following objectives:

(1) Graduates will design and develop computer hardware that reflects the exigencies imposed by software design and development considerations.

(2) Graduates will develop software that makes efficient use of current and developing hardware technologies.

(3) Graduates will continue to develop the scientific and engineering skills and knowledge that will enable them to design and implement computer systems that effectively and efficiently integrate developing hardware and software technologies.

(4) Graduates will be exposed to extensive work experiences in both the areas of computer engineering and computer science.

(5) Most graduates will enter employment in their field.

(6) Some graduates will undertake graduate education in computer engineering and/or computer science.

(7) Graduates will engage in lifelong learning and understand contemporary developments in the field.

(8) The reputations of the Electrical Engineering and Computer Science departments, which jointly sponsor the CECS program, for attracting quality students and producing quality graduates, will be continuously improved.

Bachelor of Science in Computer Engineering and Computer Science
Students attaining the Bachelor of Science degree in Computer Engineering and Computer Science would possess the scientific and engineering skills and knowledge that would enable them to design and implement computer systems that effectively and efficiently integrate developing hardware and software technologies. This degree is administered jointly by the Departments of Computer Science and Electrical Engineering.

In order to earn the Bachelor of Science degree in Computer Engineering and Computer Science, the student must: (1) earn 132 class units as described below; (2) achieve a minimum grade point average of 2.0 on all course work undertaken at USC; (3) attain a minimum grade point average of 2.0 on all course work completed in Electrical Engineering and Computer Science at USC.

The following sample four-year program is only an example of how the required courses might be scheduled. A student does not have to take the required course work in the order specified in the sample program although it would be appropriate to try and follow it as closely as possible.

Sample Four-Year Program

FIRST YEAR, FIRST SEMESTER		UNITS
CSCI 101L	Fundamentals of Computer Programming	3
MATH 125	Calculus I	4
General education*	Social Issues	4
WRIT 140*	Writing and Critical Reasoning	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
EE 101	Introduction to Digital Logic	3
EE 105	Introduction to Electrical Engineering, or	
CSCI 105	Introduction to Computer Science	3
MATH 126	Calculus II	4
General education		4
		14

SECOND YEAR, FIRST SEMESTER		UNITS
CSCI 102L	Data Structures	4
EE 102L	Introduction to Digital Circuits	2
MATH 226	Calculus III	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
General education		4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CSCI 201L	Principles of Software Development	4
EE 357	Basic Organization of Computer Systems	3
MATH 225	Linear Algebra and Differential Equations	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	
WRIT 340	Advanced Writing	3
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CSCI 271	Discrete Methods in Computer Science	4
EE 326L	Essentials of Electrical Engineering	4
EE 457	Computer Systems Organization	3
ISE 460	Engineering Economy	3
Science elective***		4
		18

THIRD YEAR, SECOND SEMESTER		UNITS
CSCI 301	Theory of Computation	3
CSCI 402	Operating Systems	3
EE 327	Digital Electronics	3
MATH 407	Probability Theory	4
General education		4
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
CSCI 303	Analysis and Design of Algorithms	3
EE 454L	Introduction to Systems Using Microprocessors	4
General education		4
Electives****	technical	6
		17

FOURTH YEAR, SECOND SEMESTER		UNITS
EE 459L CSCI 477	Senior Design Project, or Design and Construction of Large Software Systems	3 or 4
A 400-level Math course*****		4
Electives****	technical	8
		15 or 16

*Taken concurrently.

**Satisfies general education requirement for category III.

***See an advisor for a list of science courses that can satisfy this requirement.

****See an advisor for a list of courses that can satisfy the technical elective requirement. A CECS major must take a set of courses for at least one of the following four areas of specialization as part of his or her 14 technical elective units.
a. Theory — CSCI 301, CSCI 410, CSCI 430
b. Multimedia and Graphics — EE 321, CSCI 351, CSCI 480
c. Advanced Circuit Design — EE 477, EE 478, EE 479
d. Software Systems — CSCI 351, CSCI 477, CSCI 485

*****Any 400-level Mathematics course can be taken to satisfy this requirement except MATH 450.

Minor in Multimedia and Creative Technologies
See listing under Multimedia and Creative Technologies, page 533.

Graduate Degrees

The graduate program in computer engineering, offered through the Department of Electrical Engineering, is designed to provide students with an intensive background in the analysis, structure, design and function of digital computers and information processing systems. In addition to giving each student a fundamental background in digital logic, computer architecture and operating systems, a wide variety of elective courses allows for study in the following specialized areas: artificial intelligence; computer architecture; computer networks; computer system performance; design automation; fault-tolerant computers; microprocessors; parallel processing; real-time systems; robotics; and VLSI design.

Master of Science in Computer Engineering
The Master of Science in Computer Engineering is earned by completing an integrated program of at least 27 units of approved course work.

It is expected that all applicants have taken the following required courses in order to be admitted to the program. If not, the student may be required to take these courses in addition to their 27 units.

ENTRANCE REQUIREMENT COURSES		UNITS
CSCI 455	Introduction to Programming Systems Design	4
EE 357	Basic Organization of Computer Systems	3
EE 454L	Introduction to Systems Design Using Microprocessors	4

In addition, it is expected that each student in this program take or have taken the equivalent of the following fundamental courses:

FUNDAMENTAL COURSES		UNITS
CSCI 402x	Operating Systems	3
CSCI 410x	Translation of Programming Languages	4
EE 450	Introduction to Computer Networks	3
EE 457x	Computer Systems Organization	3
EE 465	Probabilistic Methods in Computer Systems Modeling	3
EE 477L	MOS VLSI Circuit Design	3

Students must take the following core courses:

CORE COURSES		UNITS
EE 557	Computer Systems Architecture	3
EE 577a	VLSI System Design	3

Depth Courses
Each student must choose one of four areas of specialization: networks, computer architecture, VLSI and CAD. Six units of depth courses must be taken in the area of specialization.

CAD: CSCI 570 or CSCI 579, EE 552, EE 599, EE 658, EE 680, EE 681.

Computer Architecture: AE 549a, CSCI 565 or CSCI 595, EE 554, EE 653, EE 657, EE 659.

Networks: CSCI 551, CSCI 558L, EE 549, EE 550, EE 555, EE 558, EE 650.

VLSI: EE 504L, EE 533ab, EE 536, EE 552, EE 577b, EE 582, EE 599, EE 630, EE 677.

Breadth Courses
The student must also take 6 units from the following list of breadth courses associated with his or her chosen area of specialization. For example, a student who chooses a spe-

cialization in VLSI must take 6 units from the VLSI breadth list.

CAD: AE 549a, CSCI 551, CSCI 565, EE 504L, EE 533a, EE 536, EE 550, EE 554, EE 555, EE 577b, EE 582, EE 657.

Computer Architecture: CSCI 551, CSCI 570, CSCI 620, EE 504L, EE 533a, EE 536, EE 549, EE 550, EE 552, EE 555, EE 577b, EE 582, EE 658, EE 680, EE 681.

Networks: AE 549a, CSCI 565, CSCI 570, EE 504L, EE 533a, EE 536, EE 552, EE 554, EE 577b, EE 582, EE 657, EE 658, EE 659, EE 680, EE 681.

VLSI: AE 549a, CSCI 551, CSCI 565, CSCI 570, EE 550, EE 554, EE 555, EE 657, EE 658, EE 659, EE 680, EE 681.

A minimum grade point average of 3.0 (A = 4.0) must be earned on all course work applied toward the master's degree in computer engineering. This average must also be achieved on all 400-level and above course work attempted at USC beyond the bachelor's degree. Transfer units which count as credit (CR) toward the master's degree are not computed in the grade point average. All other School of Engineering requirements for the Master of Science apply. For the M.S. in Electrical Engineering (VLSI Design) and the M.S. in Electrical Engineering (Computer Network) degrees section, see page 507.

Doctor of Philosophy in Computer Engineering

The requirements for the Doctor of Philosophy (Ph.D.) degree in computer engineering are in strict conformity with the requirements of the Graduate School. Program requirements for the Ph.D. in computer engineering are the same as those for the Ph.D. in electrical engineering except that the major field is computer engineering. See general requirements for graduate degrees.

Screening and qualifying examinations are administered by the computer engineering faculty. Students should contact the Electrical Engineering-Systems Department Office for further information.

Major Areas in Computer Engineering and Relevant Courses (not applicable to M.S., Computer Engineering requirements)

COMPUTER SYSTEMS ARCHITECTURE		UNITS
EE 457x	Computer Systems Organization	3
EE 554	Real Time Computer Systems	3
EE 557	Computer Systems Architecture	3
EE 653	Multithreaded Architectures, Data-Flow Computing and Functional Programming	3
EE 657	Parallel Processing	3
EE 659	Interconnection Networks	3

ARTIFICIAL INTELLIGENCE		UNITS
CSCI 544	Natural Language Processing	3
CSCI 561a	Artificial Intelligence	3
CSCI 574	Computer Vision	3
CSCI 598	Expert Systems	3
CSCI 674a	Advanced Topics in Computer Vision	3
EE 559	Mathematical Pattern Recognition	3

ROBOTICS		UNITS
CSCI 545	Robotics	3
CSCI 547	Sensing and Planning in Robotics	3
EE 546L	Basic Robotics	1
ME 548	Analytical Methods in Robotics	3
ME 541	Linear Control Systems II	3

COMPUTER NETWORKS AND DISTRIBUTED SYSTEMS		UNITS
CSCI 551	Computer Communications	3
CSCI 555	Advanced Operating Systems	3
CSCI 579	Graph and Combinatorial Algorithms	3
EE 450	Introduction to Computer Networks	3
EE 549	Queueing Theory for Performance Modeling	3
EE 550	Design and Analysis of Computer Communication Networks	3
EE 555	Broadband Network Architectures	3
EE 650	Advanced Topics in Computer Networks	3

DIGITAL SYSTEMS DESIGN		UNITS
EE 552	Logic Design and Switching Theory	3
EE 577ab	VLSI System Design	3-2
EE 582	Technical Seminar on VLSI Design	1
EE 658	Diagnosis and Design of Reliable Digital Systems	3
EE 680	Computer Aided Design of Digital Systems I	3
EE 681	Computer-Aided Design of Digital Systems II	3

Computer Science

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Chair: Michael Arbib, Ph.D.

Faculty

Gordon S. Marshall Chair in Engineering: George A. Bekey, Ph.D.

Henry Salvatori Chair in Computer Science: Leonard Adleman, Ph.D.

Charles Lee Powell Chair in Electrical Engineering and Computer Engineering: Melvin Breuer, Ph.D. (*Electrical Engineering*)

David Packard Chair in Manufacturing Engineering: Stephen C-Y. Lu, Ph.D. (*Mechanical Engineering, Industrial and Systems Engineering)*

TRW Professorship in Software Engineering: Barry Boehm, Ph.D.

Professors: Michael Arbib, Ph.D. (*Biomedical Engineering, Electrical Engineering, Neurobiology and Psychology*); Irving Biederman, Ph.D. (*Psychology*); Edward K. Blum, Ph.D. (*Mathematics*); Deborah Estrin, Ph.D.; Ellis Horowitz, Ph.D. (*Electrical Engineering*); Ming-Deh Huang, Ph.D.; Kai Hwang, Ph.D. (*Electrical Engineering*); Dennis McLeod, Ph.D.; Gerard Medioni, Ph.D.; Ramakant Nevatia, Ph.D.; Pavel Pevzner, Ph.D. (*Mathematics*); Aristides Requicha, Ph.D. (*Electrical Engineering*); Paul Rosenbloom, Ph.D.; Mark Seidenberg, Ph.D. (*Psychology, Linguistics*); Christoph von der Malsburg, Ph.D. (*Neurobiology, Physics and Astronomy*); Michael Waterman, Ph.D. (*Mathematics, Biological Sciences*)

Associate Professor: Shahram Ghandeharizadeh, Ph.D.

Assistant Professors: Mathieu Desbrun, Ph.D.; Ashish Goel, Ph.D.; Maja Mataric, Ph.D.; Neno Medvidovic, Ph.D.; Ulrich Neumann, Ph.D.; Christos Papadopoulos, Ph.D.; Stefan Schaal, Ph.D.

Adjunct Professor: Sukhan Lee, Ph.D.

Adjunct Associate Professor: Scott Shenker, Ph.D.

Adjunct Assistant Professors: Steve Chien, Ph.D.; Robert Felderman, Ph.D.; Douglas Ierardi, Ph.D.; Raymond Madachy, Ph.D.; Larry Matthies, Ph.D.; Xin Wang, Ph.D.

Research Professors: Robert M. Balzer, Ph.D.; Herbert Schorr, Ph.D.; David Wile, Ph.D.

Research Associate Professors: Eduard Hovy, Ph.D.; Lewis Johnson, Ph.D.; Carl Kesselman, Ph.D.; Craig Knoblock, Ph.D.; Steven Minton, Ph.D.; Robert Neches, Ph.D.; Keith Price, Ph.D.; William Swartout, Ph.D.; Gene Tsudik, Ph.D.

Research Assistant Professors: Cengiz Alaettinoglu, Ph.D.; Anindo Banerjea, Ph.D.; Isaac Cohen, Ph.D.; Pedro Diniz, Ph.D.; Martin Frank, Ph.D.; Yolanda Gil, Ph.D.; Ramesh Govindan, Ph.D.; Jonathan Gratch, Ph.D.; Mary Hall, Ph.D.; John Heidemann, Ph.D.; Randall Hill, Ph.D.; Kevin Knight, Ph.D.; Daniel Marcu, Ph.D.; David Moriarty, Ph.D.; Clifford Neuman, Ph.D.; Katia Obraczka, Ph.D.; Dan Port, Ph.D.; Jeff Rickel, Ph.D.; Cyrus Shahabi, Ph.D.; Wei-Min Shen, Ph.D.; Gaurav Sukhatme, Ph.D.; Pedro Szekely, Ph.D.; Milind Tambe, Ph.D.; Joseph Touch, Ph.D.; Richard Weinberg, Ph.D. (*Cinema-Television*); Wayne Zhang, Ph.D.

Lecturers: Claire Bono; Michael Crowley, Ph.D.; Massoud Ghyám-Khan

Emeritus Professors: Seymour Ginsburg, Ph.D.; Irving S. Reed, Ph.D. (*Electrical Engineering*)

Bachelor of Science

Bachelor of Science in Computer Science

The undergraduate program in computer science is an interdisciplinary program leading to the Bachelor of Science in Computer Science. The program is designed to provide both an academic and professional orientation.

General admission requirements for the undergraduate program are the same as those of the university and the USC School of Engineering and include three to five units of mathematics and one unit of science (biology, chemistry or physics) together with satisfactory scores on the Scholastic Aptitude Test and Achievement Tests. The requirement for the degree is 128 units. A cumulative scholarship average of C (2.0) is required for all courses

taken at USC as well as for all computer science courses taken in the program. Computer science is a department in the USC School of Engineering; however, the Bachelor of Science degree with a major in computer science is awarded through the USC College of Letters, Arts and Sciences. Candidates must complete general education requirements; see page 169.

Computer science students may take two of the following ITP courses for free elective credit: ITP 111x, 160x, 165x, 225x or 275x.

FIRST YEAR, FIRST SEMESTER		UNITS
CSCI 101L	Fundamentals of Computer Programming	3
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CSCI 102L	Data Structures	4
CSCI 105	Introduction to Computer Science	3
MATH 126	Calculus II	4
General education or foreign language		4
		15

SECOND YEAR, FIRST SEMESTER		UNITS
CSCI 201L	Principles of Software Development	4
CSCI 271	Discrete Methods in Computer Science	4
EE 101	Introduction to Digital Logic	3
General education or foreign language		4
		15

SECOND YEAR, SECOND SEMESTER		UNITS
CSCI 402x	Operating Systems	3
EE 102L	Introduction to Digital Circuits	2
MATH 225	Linear Algebra and Differential Equations	4
Basic science requirement 1**		4
General education or foreign language		4
		17

THIRD YEAR, FIRST SEMESTER		UNITS
CSCI 301	Theory of Computation	3
EE 357	Basic Organization of Computer Systems	3
400-level Mathematics elective****		4
Basic science requirement 2**		4
WRIT 340	Advanced Writing	3
		17

THIRD YEAR, SECOND SEMESTER		UNITS
CSCI 303	Design and Analysis of Algorithms	3
EE 457x	Computer Systems Organization	3
Additional science ***		4
General education or foreign language		4
Free elective		3
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
CSCI 410x	Translation of Programming Languages	4
CSCI technical electives		6
General education or foreign language		4
Free elective		4
		18

FOURTH YEAR, SECOND SEMESTER		UNITS
CSCI technical electives		6
General education		8
		14

*Taken concurrently.

**Basic science requirement: PHYS 151L and 152L or CHEM 105abL or BISC 110L and 112L.

***Any course in physics, biology or chemistry beyond the basic science requirement or in another scientific discipline. See department for approval.

****Any 400-level mathematics course except MATH 450.

Foreign Language Requirement
Three semesters of a single language and passing the skill level examination in that language or passing the skill level examination in a foreign language.

Technical Electives (four courses)
Four upper division computer science courses.

Physics/Computer Science Major Requirements for the Bachelor of Science
This program is intended for students with dual interests in physics and computer science who wish to complete the essential courses for both majors within their normal four year career. See the Physics and Astronomy Department section, page 329 for course requirements.

Bachelor of Science in Computer Engineering and Computer Science
See the listing under Computer Engineering, page 495.

Bachelor of Science in Computer Science (Manufacturing Engineering)
If a student chooses six courses (9 to 18 units) from a prescribed program, he or she may graduate with the special designation Area of Emphasis in Manufacturing Engineering on the transcript. Details are given under Manufacturing Engineering on page 524.

Minor in Multimedia and Creative Technologies
See listing under Multimedia and Creative Technologies, page 533.

Graduate Degrees

The requirements listed below are special to this department and must be read in conjunction with the general requirements of the USC School of Engineering for master's degrees and the general requirements of the USC Graduate School for Ph.D. degrees, page 565. The graduate program in computer science provides intensive preparation in the basic concepts and techniques related to the design, programming and application of digital computers. Both the Master of Science and Doctor of Philosophy degrees are offered.

A master of science degree with specialization in Software Engineering is also offered. The program seeks to prepare students for an industrial leadership career in software engineering. It also serves as an introduction to this area for students who wish to pursue advanced studies and research leading to a Ph.D.

A master of science degree with specialization in Robotics and Automation is also offered. This program seeks to prepare students for an industrial career in the development of computer systems for CAD/CAM (Computer-Aided Design and Manufacturing) and robotics. It also serves as an introduction to this area for students who wish to pursue advanced studies and research leading to a Ph.D. The emphasis is on the domain of mechanical, electromechanical and mechatronic products. (CAD for digital systems is covered by a separate program offered by the Electrical Engineering-Systems Department.)

A master of science degree with a specialization in computer networks is offered. This specialization prepares students in the areas of computer communications, networks and distributed processing.

A master of science in computer science (multimedia and creative technologies) is also offered, page 533.

A master of science in computational linguistics is also offered as a separate program in conjunction with the Linguistics Department. See the listing under Linguistics, page 303.

A master of science in integrated systems is offered. See the listing under Multimedia and Creative Technologies, page 533.

Admission and Prerequisites
Admission is determined by the Office of Admissions in consultation with the Computer Science Department. The applicant is required to have a bachelor's degree or its equivalent from an accredited college or university; satisfactory scores on the verbal and quantitative portions of the aptitude test of the Graduate Record Examinations (one advanced test from computer science, mathematics or engineering is recommended); substantial background in computing — the equivalent of USC's undergraduate courses CSCI 101L, 102, 110, 201, EE 357 — constitutes a minimum requirement; and completion of several courses in college level mathematics (at minimum, one discrete mathematics course). Students lacking these prerequisites should complete them at other institutions. Foreign students must earn a satisfactory score on the Test of English as a Foreign Language.

DEFICIENCY REQUIREMENTS		UNITS
CSCI 301	Theory of Computation	3
CSCI 402x	Operating Systems	3
CSCI 410x	Translation of Programming Languages	4
EE 457x	Computer Systems Organization	3

All applicants for the master's program should have a general breadth in computer science equivalent to the above-listed USC undergraduate courses. Unsatisfactory background in any of these courses is considered a deficiency. Conditional admission may be granted to otherwise qualified students with breadth requirement deficiencies. Students with deficiencies in breadth requirements must take the appropriate courses at USC. All master's students must have an official form from the Computer Science Department in their academic records as the evidence of fulfillment of the breadth requirement, prior to completion of their program of study. No student may take any of the deficiency courses listed above for credit toward a graduate degree in Computer Science.

Master of Science
A minimum grade point average of 3.0 must be earned on all course work applied toward the master's degree in computer science. This average must also be achieved on all 400-level and above course work attempted at USC beyond the bachelor's degree. Transfer units count as credit (CR) toward the master's degree and are not computed in the grade point average. The required courses are three

of the following seven courses: EE 557, CSCI 555, 561a or 561b, 565, 571, 577a and 585. A maximum of nine units may be taken at the 400 level in either electrical engineering or computer science; the remaining units must be approved courses at the 500 or 600 level. CSCI 590 may be counted for a maximum of six units. Total units required for the degree is 27. No examination or master's thesis is required for the degree. Other requirements for the Master of Science in Computer Science are the same as set forth in the general requirements for School of Engineering master's degrees.

Master of Science with Specialization in Computer Networks
Under the networks option students must satisfy the requirements for the Master of Science in Computer Science and the following courses must be included in the program: EE/CSCI 450; EE 465 or EE 549; EE 550; CSCI 551, 555, 558; CSCI 590 or 694a or b. Total units required for the degree is 27. Students who can demonstrate that they have already taken these courses (or equivalent) may be waived out of the requirement by a memo from their faculty advisor. All courses must be approved by a faculty advisor. A list of suggested electives is available from the department office.

Master of Science in Computer Science (Multimedia and Creative Technologies)
See the listing under Multimedia and Creative Technologies, page 533.

Master of Science with Specialization in Software Engineering
Students must satisfy all requirements for the Master of Science degree in Computer Science. In addition, they must take the following courses, CSCI 510, 577ab and 578, plus three of the following five courses: CSCI 511, 555, 585, 588 and EE 557 (EE 557, CSCI 555, 577a, and 585 may be used to satisfy both the general master's degree requirements and the specialization requirements.) Students may also include research for an optional master's thesis in their programs.

Master of Science with Specialization in Robotics and Automation
Students must take CSCI 545 and three of the following four courses: CSCI 561a, 574, 582 and 584. Other requirements are the same as for the Master of Science degree in Computer Science, described above. (CSCI 561a may be used to help satisfy both the general master's requirements and the specialization requirements.) Students may include in their programs research for an optional master's thesis conducted in collaboration with industry.

Master of Science in Computational Linguistics
See the listing under Linguistics, page 303.

Doctor of Philosophy in Computer Science
The Doctor of Philosophy degree in computer science is awarded in strict conformity with the general requirements of the USC Graduate School.

Admission to the Ph.D. program in Computer Science is highly selective, based upon a superior academic record, prior training in computer science, letters of recommendation, a statement of purpose and Graduate Record Examinations scores. Particular attention is given to the applicant's potential to perform original research in an area of computer science. Once admitted, the progress of each Ph.D. student is reviewed once a semester by the entire faculty and a determination is made as to whether the student will be allowed to continue in the program. Since research potential is a key factor in the evaluation, new students are strongly urged to begin research with a Computer Science faculty member as soon as possible. See general requirements for graduate degrees.

Screening Procedure
When a student has completed 21 units or more of graduate level studies in computer science at USC, he or she must apply for screening. The screening evaluation takes place during the regular review of Ph.D. students; based upon the student's performance in course work, overall record, and research potential, the screening evaluation determines whether or not the student will be allowed to continue toward the Ph.D. A screening determination of "pass," "no pass" or "postpone" is made; in the latter case, the student must reapply for screening the subsequent semester(s) until a "pass" or "no pass" determination is made.

Guidance Committee
After passing the screening procedure, the student must select a dissertation advisor and form a guidance committee consisting of the dissertation advisor and at least four other faculty members. The committee must include a faculty member from another department who does not hold a joint appointment in Computer Science. All guidance committees must be approved by the department chair and the Graduate School.

Course Requirements
Each Ph.D. student is expected to demonstrate breadth of knowledge as well as depth in a chosen area of concentration. Hence, the required courses fall into two groups: (1) a common core, required of all doctoral students, and (2) additional required courses which depend on the student's area of concentration. The common core consists of five courses selected from the following

three groups: systems group: CSCI 551, CSCI 555, CSCI 565, CSCI 571, CSCI 577a, CSCI 585, EE 557; theory group: CSCI 570, CSCI 572, CSCI 581; artificial intelligence group: CSCI 545 or CSCI 547 or CSCI 584, CSCI 561a, or CSCI 561b, CSCI 564, CSCI 574, CSCI 582. Students must take two courses from two groups and one course from the third group. A minimum GPA of 3.5 must be obtained in these five core courses.

Ph.D. programs in computer science are grouped into the following three tracks: (1) theoretical computer science; (2) language, systems and applications; (3) artificial intelligence, robotics and neural computation.

Each student must select a track as his or her area of concentration. Each track requires a minimum of three additional courses. Specific track requirements (which may change as the fields change) will be provided to the students by the department.

Required courses may be taken in any chronological order, with due attention to prerequisites, and may precede or follow the Screening Evaluation.

Deficiencies
In addition to the above, all doctoral students must have knowledge of the material covered in CSCI 271, 301 or 430, CSCI 402, 410, EE 457Lx; these subjects are considered "deficiency courses."

A total of 60 units, at least 40 at the 500 level or above, beyond the bachelor's degree is required (including the above required courses). A minimum grade point average of 3.5 must be maintained. Students with a Master of Science degree may transfer up to 27 units.

Qualifying Examination
All doctoral students must pass a qualifying examination in computer science within four years before being admitted to candidacy. The qualifying examination tests the student's broad knowledge of computer science and deep insight into a chosen area of research.

Permission to take the qualifying examination must be obtained from the dean of graduate studies at least 60 days prior to its occurrence, and must be taken in the semester for which permission is granted. The guidance committee administers the qualifying examination and evaluates the student's performance. If the examination is failed, the guidance committee may recommend that the student repeat the examination 6-12 months later. The examination cannot be taken more than twice.

Dissertation
An acceptable dissertation based upon original research is required. The dissertation must show mastery of some special field, must be an original contribution to that field and must be presented in scholarly form.

Defense of the Dissertation
When all other requirements are satisfied, the candidate must pass a public final oral examination in defense of the dissertation.

Courses of Instruction

COMPUTER SCIENCE (CSCI)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

101L Fundamentals of Computer Programming (3, FaSp) Introduction to the design of solutions to computer solvable problems. Algorithm design, solution implementation using a high-level programming language, program correctness and verification.

102L Data Structures (4, FaSp) Linear lists, strings, arrays, and orthogonal lists; graphs, trees, binary trees, multilinked structures, sorting techniques; dynamic storage allocation; applications. *Prerequisite:* CSCI 101*L*.

105 Introduction to Computer Science (3, Sp) Gateway to the bachelor of science in computer science and computer engineering and computer science. An introduction to the discipline of computer science. The study of the history, ethics, legal issues, and subdisciplines of computer science using the Java language.

110 Introduction to Digital Logic (3) (Enroll in EE 101)

201L Principles of Software Development (4, FaSp) The object-oriented paradigm for programming-in-the-large (using the C++ language); UNIX tools for software development; developing window-based applications under X-windows. *Prerequisite:* CSCI 102.

271 Discrete Methods in Computer Science (4, FaSp) Models for discrete structures in computer science, including selected applications of logic, induction, recursion and graphs to program correctness, design algorithms, programming language semantics and databases. *Corequisite:* CSCI 102.

301 Theory of Computation (3, FaSp) Finite state automata, regular sets; context-free grammar, pushdown automata; Turing machines, undecidability, the halting problem, Church's thesis, recursive functions, effective procedures. *Prerequisite:* CSCI 102 and CSCI 271.

303 Design and Analysis of Algorithms (3, FaSp) Design techniques including backtracking, dynamic programming, divide and conquer, data structure, fast Fourier transform; finite combinatorial mathematics. *Prerequisite:* CSCI 102 and CSCI 271.

351 Programming and Multimedia on the World Wide Web (3, Sp) HTML programming for creating home pages, installation and modification of Web server, writing programs that offer enhanced services, manipulation of graphics, video and sound. *Prerequisite:* CSCI 201.

357 Basic Organization of Computer Systems (3) (Enroll in EE 357)

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

402x Operating Systems (3, FaSp) Basic issues in concurrency, deadlock control, synchronization scheduling, memory management, protection and access control, interprocess communication, and structured design. Laboratory experiences with Unix-like operating system. Not available for graduate credit to computer science majors. *Prerequisite:* CSCI 201*L* or CSCI 455*x*.

410x Translation of Programming Languages (4, Fa) Concepts of assemblers, compilers, interpreters and their design; macro assemblers, Polish notation and translation techniques; operator precedence parsing, code generation. Not available for graduate credit to computer science majors. *Prerequisite:* CSCI 201; *corequisite:* EE 357.

430 Finite Automata Theory (3) Regular sets; finite state acceptors; right-linear grammar; finite state machines; set operations; Kleene theorem; state minimization; incomplete state reduction; selected other topics. *Prerequisite:* CSCI 301 or MATH 410 or departmental approval.

445 Introduction to Robotics (4, Fa) Designing, building and programming mobile robots; sensors, effectors, basic control theory, control architectures, some advanced topics, illustrations of state-of-the-art. Teamwork; final project tested in a robot contest. Junior standing or higher. *Prerequisite:* CSCI 101*L* or C language programming.

446 Robotics and Sensing for Automated Assembly (3) Fundamental principles of mechanics of parts and devices for automated assembly. Robots, parts feeders, automated guided vehicles, industrial sensing. Programming of robots and sensors. Junior or senior standing or departmental approval. *Prerequisite:* CSCI 101*L*.

450 Introduction to Computer Networks (3) (Enroll in EE 450)

454L Introduction to Systems Design Using Microprocessors (4) (Enroll in EE 454*L*)

455x Introduction to Programming Systems Design (4, FaSp) Intensive introduction to programming principles, discrete mathematics for computing, software design and software engineering concepts. Not available for credit to computer science majors, graduate or undergraduate. *Prerequisite:* departmental approval.

457x Computer Systems Organization (3) (Enroll in EE 457*x*)

458 Numerical Methods (4) (Enroll in MATH 458)

460 Introduction to Artificial Intelligence (3, FaSp) Concepts and algorithms underlying the understanding and construction of intelligent systems. Agents, problem solving, search, representation, reasoning, planning, communication, perception, robotics, neural networks. Junior standing. *Prerequisite:* CSCI 102*L* or CSCI 455*x*.

465 Probabilistic Methods in Computer Systems Modeling (3) (Enroll in EE 465)

477L Design and Construction of Large Software Systems (4, Sp) Programming methodologies; intra-group and inter-group communication; software life-cycle; software economics. A large software project is a central aspect of the course. Laboratory. *Prerequisite:* CSCI 102.

480 Computer Graphics (3, FaSp) Hardware for interactive graphic systems; picture representations; data structures for graphics; picture processing techniques; languages for graphics; survey of applications such as animation and simulation. *Prerequisite:* CSCI 102.

482 Introduction to Geometric Modeling (3, Sp) Role of geometry in CAD/CAM. Graphic user interfaces; motions and projections; cubes, surfaces and solids; fundamental algorithms. Applications in analysis, manufacturing, inspection and robots. Junior or senior standing. *Prerequisite:* CSCI 101 or departmental approval.

485 File and Database Management (3, FaSp) File input/output techniques, basic methods for file organization, file managers, principles of databases, conceptual data models, and query languages. *Prerequisite:* CSCI 201.

490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

495 Senior Project (3) (Enroll in PHYS 495)

499 Special Topics (2-4, max 8) Selected topics in computer science.

501 Numerical Analysis and Computation (3) (Enroll in MATH 501)

502ab Numerical Analysis (3-3) (Enroll in MATH 502*ab*)

504ab Numerical Solutions of Ordinary and Partial Differential Equations (3) (Enroll in MATH 504*ab*)

505ab Applied Probability (3-3) (Enroll in MATH 505*ab*)

510 Software Management and Economics (3, Fa) Theories of management and their application to software projects. Economic analysis of software products and processes. Software cost and schedule estimation, planning and control. *Prerequisite:* graduate standing.

511 Personal Software Process (PSP) and Project (3, Sp) Individual analysis, planning, development and maintenance of a software product or development artifact, using the principles and practices of PSP. Analysis of project's lessons learned. *Prerequisite:* CSCI 577*a*.

533 Combinatorial Analysis and Algebra (3) (Enroll in MATH 533)

541 Reasoning about Actions and Plans (3, Irregular) Foundations and techniques of automated planning, including representations of actions and plans, approaches to planning, controlling search, learning for planning, and interaction with the environment. *Prerequisite:* CSCI 561*b*.

542 Neural Computation with Artificial Neural Networks (3, Sp) Computation and adaptation in networks of interconnected distributed processing units; classical and statistical approaches to neural nets; state-of-the-art neural network research. *Recommended preparation:* basic statistics, linear algebra.

544 Natural Language Processing (3) Examination of the issues which enable computers to employ and understand natural language; knowledge representation, memory modeling, parsing, language analysis, story understanding, and generation. *Prerequisite:* CSCI 460 or CSCI 561*b* or departmental approval.

545 Robotics (3, Sp) Fundamental skills for programming robots for industrial applications; spatial transforms and kinematics; geometric algorithms for identifying, avoiding, grasping, and relocating objects; current research issues. Duplicates credit in CSCI 445. *Prerequisite:* C-language programming.

547 Sensing and Planning in Robotics (3, Fa) Introduction to software methods in robotics including sensing, sensor fusion, estimation, fault tolerance, sensor planning, robot control architectures, planning and learning. *Prerequisite:* CSCI 561*a*.

551 Computer Communications (3, Sp) Protocol design for computer communication networks, network routing, transport protocols, internetworking. *Prerequisite:* CSCI 402, EE 450 and C-language programming.

552 Logic Design and Switching Theory (3) (Enroll in EE 552)

553 Computational Solution of Optimization Problems (3) (Enroll in EE 553)

554 Real Time Computer Systems (3) (Enroll in EE 554)

555 Advanced Operating Systems (3, FaSp) Advanced issues in computer organization, naming, kernel design, protection mechanisms and security policies, reliable computing, data base OS, secure networks, systems specification, decentralized systems, real time systems. *Prerequisite:* CSCI 402.

556 Introduction to Cryptography (3) Modern secret codes. Public key cryptosystems of Rivest-Shamir-Adelman, Diffie-Hellman and others. The underlying number theory and computational complexity theory. *Prerequisite:* CSCI 570 or CSCI 572 or CSCI 581.

557 Computer Systems Architecture (3) (Enroll in EE 557)

558L Internetworking and Distributed Systems Laboratory (3) Students complete laboratory exercises in operating system and network management, distributed systems, TCP/IP, SNMP, NFS, DNS, etc. Term project required. *Prerequisite:* CSCI 402 and EE/CSCI 450; *Recommended preparation:* CSCI 551 and CSCI 555.

559 Mathematical Pattern Recognition (3-3) (Enroll in EE 559)

560L Advanced Microcomputer-Based Design (3) (Enroll in EE 560*L*)

561ab Artificial Intelligence (3-3, FaSp) *a:* Foundations of symbolic intelligent systems. Agents, search, problem solving, representation, reasoning and symbolic programming. *Prerequisite:* CSCI 455*x*. *b:* Advanced capabilities for symbolic intelligent systems. Planning, reasoning under uncertainty, decision making, learning, natural language communication. *Prerequisite:* CSCI 561*a*.

562 Empirical Methods in Natural Language Processing (3, 2 years, Fa) Acquiring computer-tractable linguistic knowledge has always been a bottleneck in building natural language systems. We will examine statistical techniques for extracting knowledge automatically from online text. *Prerequisite:* CSCI 561*a*.

563 Applications of Natural Language Processing (3, 2 years, Fa) Having learned the basic symbolic and statistical techniques of computational language processing, students in this course learn to apply them in two or more practical application areas. *Prerequisite:* CSCI 544.

564 Brain Theory and Artificial Intelligence (3, Fa) Introduces neural modeling, distributed artificial intelligence and robotics approaches to vision, motor control and memory. *Prerequisite:* graduate standing.

565 Compiler Design (4, Sp) Formal grammar; parsing methods and lexical analysis; code generation; local and global code optimization; and dynamic allocation. *Prerequisite:* CSCI 455*x*.

566 Neural Network Self-Organization (3, Sp) Differential equations for network pattern formation. Dynamic link architecture. Simulation of brain organization processes (retinotopy, orientation columns) and face recognition by elastic matching. *Recommended preparation:* CSCI 564 and either MATH 225 or MATH 245.

567 Machine Learning (3) The study of self-modifying computer systems that acquire new knowledge and improve their own performance. Topics include induction, explanation-based learning, analogy, discovery, and connectionist learning. *Prerequisite:* CSCI 561*b*.

568 Commonsense Reasoning (3) Formalism for representing commonsense knowledge about quantities, time, space, physics, minds, plans, goals and society. Methods for making commonsense inferences. *Prerequisite:* CSCI 561*b*.

569 Integrated Intelligent Systems (3) Approaches to solving the artificial intelligence problem: combining components of intelligent behavior – learning, problem solving, planning, knowledge, language, perception, action – into integrated intelligent systems. *Prerequisite:* CSCI 561*b*.

570 Analysis of Algorithms (3, FaSp) Explores fundamental techniques such as recursion, Fourier transform ordering, dynamic programming for efficient algorithm construction. Examples include arithmetic, algebraic, graph, pattern matching, sorting, searching algorithms.

571 Issues of Programming Language Design (3, Fa) Advanced study of programming languages with application to the Web. Languages for client-side and server-side processing. Examples taken from: HTML, Java, JavaScript, Perl, SML and others. *Recommended preparation:* knowledge of at least two programming languages.

572 Advanced Theory of Computation (3) Machine models of effective computability; subrecursive hierarchies; P and NP problems; effective and efficient reducibility; time, space, and abstract complexity. *Prerequisite:* CSCI 301 or departmental approval.

574 Computer Vision (3, Fa) Description and recognition of objects, shape analysis, edge and region segmentation, texture, knowledge based systems, image understanding. *Prerequisite:* CSCI 455*x*.

575 Neuroinformatics (3, Sp) Introduces databases, WWW, data mining, visualization and simulation for complex neuroscience data. Team projects will unite graduate students in computer science, neuroscience and related disciplines. Graduate standing. *Prerequisite:* CSCI 564 or BISC 421.

576 Multimedia Systems Design (3, FaSp) State-of-the-art technology for networked multimedia systems such as: system design, I/O technologies, data management, data compression, networking and telecommunications. Design of real-world multimedia solution. *Recommended preparation:* familiarity with C or C++.

577ab Software Engineering (4-4, FaSp) *a:* Software life cycle processes; planning considerations for product definition, development, test, implementation, maintenance. Software requirements elicitation and architecture synthesis. Team project. *b:* Software development, test, implementation, and maintenance methods. CASE tools and software environments. Software product engineering, configuration management, quality engineering, documentation. Application via projects. *Prerequisite: a:* graduate standing; *b:* CSCI 577*a*.

578 Software Architectures (3, Sp) Study of concepts, principles and scope of software system architectures, including architectural styles, languages, connectors, middleware, dynamism, analysis, testing and domain-specific approaches. *Prerequisite:* CSCI 577*a*.

579 Graph and Combinatorial Algorithms (3) Review of basic graph theory and graph searching, connectivity, flows, matching, ear decomposition, planarity, NP-completeness, sorting, geometric algorithms, parallel algorithms, parallel random access machines. *Prerequisite:* CSCI 303.

580 3D Graphics and Rendering (3, Fa) The process of creating images from 3D models. Includes transformations, shading, lighting, rasterization, texturing, and other topics. *Prerequisite:* CSCI 480.

581 Logic and its Applications (3) Formal systems, first order logic, truth, completeness, compactness, Godel incompleteness, recursive functions, undecidability. Selected applications, e.g., theorem proving, artificial intelligence, program verification, databases, computational complexity. *Prerequisite:* CSCI 430 and MATH 470.

582 Geometric Modeling (3, Sp) Mathematical models and computer representations for three-dimensional solids; underlying topics from set theory, geometry, and topology. Fundamental algorithms; applications to CAD/CAM and robotics. *Prerequisite:* EE 441 and CSCI 102 or equivalent knowledge of linear algebra and data structures.

583 Computational Geometry (3) Geometric algorithms from graphics, vision, geometric modeling, and optimization are studied in a unified way. Topics include proximity, motion planning, Voronoi diagrams, convex hulls. *Prerequisite:* CSCI 303.

584 Control and Learning in Multi-Robot/ Agent Systems (3, Sp) Survey of control and learning methods from technical papers. Distributed multi-robot/agent systems. Mobile robotics, distributed AI, control architectures, adaptation, learning, cooperative and competitive systems. *Prerequisite:* CSCI 460 or CSCI 445 or CSCI 561*a*.

585 Database Systems (3, FaSp) Database system architecture; conceptual database models; semantic, object-oriented, logic-based, and relational databases; user and program interfaces; database system implementation; integrity, security, concurrency and recovery. *Prerequisite:* CSCI 485 or departmental approval.

586 Database Systems Interoperability (3, Sp) Federated and multi-database systems, database networking, conceptual and schematic diversity, information sharing and exchange, knowledge discovery, performance issues. *Prerequisite:* CSCI 585.

587ab Mathematical Models of Neurons and Neural Networks (3-3) (Enroll in MATH 587*ab*)

588 Specification and Design of User Interface Software (3, Fa) The design and implementation of user interface software. Study of issues relating to human/computer interaction. Visual design and real-time interfaces. *Prerequisite:* CSCI 577*a*.

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

593 Autonomous Learning and Discovery Agents (3) Active systems, using their own actions, percepts, and mental constructions, abstract a model from an unfamiliar environment in order to accomplish their missions. *Prerequisite:* CSCI 561*b*.

595 Advanced Compiler Design (4) Code generation, data-flow analysis, global optimization, register allocation, data dependency analysis, unimodular transformations, vectorization, parallelization, data and computation decomposition. *Prerequisite:* CSCI 565.

598 Knowledge Based Systems (3) Comparative studies of classical expert systems, real-time systems, intelligent agents; techniques of rule, model, constraint-based and probabilistic reasonings; tools for knowledge acquisition. *Prerequisite:* CSCI 561*b* or departmental approval.

599 Special Topics (2-4, max 9) Course content to be selected each semester from recent developments in computer science.

620 Design and Analysis of Parallel Computation (3) Routing and algorithm design for parallel machines. PRAM model, fixed connection models, circuit depth, randomization. Parallel algorithms including independent set, matching, evaluation, linear system, sparse techniques. *Prerequisite:* CSCI 570.

658 Diagnosis and Design of Reliable Digital Systems (3) (Enroll in EE 658)

664 Neural Models for Visually Guided Behavior (3, max 9) Review of neural mechanisms of visuo-motor coordination, and methods for constructing models of these mechanisms. Topics include locomotion, cognitive maps, looking, reaching and grasping. *Prerequisite:* CSCI 564.

667 Seminar in Advanced Topics in Machine Learning (2) Seminar covering the latest results published in the field of machine learning and the research currently ongoing at USC. *Prerequisite:* CSCI 567.

674ab Advanced Topics in Computer Vision (3-3) Selected topics from current active research areas including image segmentation, shape analysis and object recognition, inference of 3-D shape, motion analysis, knowledge-based system, neural nets. *Prerequisite:* CSCI 574 or CSCI 569.

694ab Topics in Computer Networks and Distributed Systems (3-3) Current topics in network and distributed systems; verbal and written presentation skills, effective critiquing, and evaluation. *Prerequisite:* CSCI 551 and CSCI 555.

695 Seminar in Advanced Database Systems (1-4) Study of recent literature on techniques in database systems. Emphasis on developing skills in critical reading, technical writing, oral presentation, and database implementation techniques. Departmental approval is required. *Prerequisite:* CSCI 484 or CSCI 585.

790 Research (1-12) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Electrical Engineering

Electrical Engineering-Systems
Hughes Aircraft Electrical Engineering Center
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Email: eesystem@ee.usc.edu

Electrical Engineering-Electrophysics
Powell Hall of Information Sciences and Engineering 604
(213) 740-4700
FAX: (213) 740-8677
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Co-Chairs: Robert A. Scholtz, Ph.D. (*Systems*); Martin Gundersen, Ph.D. (*Electrophysics*)

Associate Chair (Systems): Melvin Breuer, Ph.D. (*Computer Science*)

Associate Chair (Electrophysics): Hans H. Kuehl, Ph.D.

Faculty

Zohrab A. Kaprielian Dean's Chair in Engineering: Leonard M. Silverman, Ph.D.

Lloyd F. Hunt Chair in Electrical Power Engineering: Tsen-Chung Cheng, Sc.D.

William M. Keck Chair in Engineering: P. Daniel Dapkus, Ph.D.

George T. Pfleger Chair in Electrical Engineering: Robert W. Hellwarth, Ph.D. (*Physics*)

Charles Lee Powell Chair in Electrical Engineering and Computer Science: Melvin Breuer, Ph.D. (*Computer Science*)

William M. Hogue Professorship in Electrical Engineering: William H. Steier, Ph.D.

Northrop Assistant Professorship in Electrical Engineering: Sandeep K. Gupta, Ph.D.

Professors: Michael Arbib, Ph.D. (*Computer Science, Neurobiology, Biomedical Engineering*); Stanley P. Azen, Ph.D. (*Preventive Medicine and Biomedical Engineering*); George A. Bekey, Ph.D. (*Computer Science and Biomedical Engineering and Speech Science and Technology*); Melvin Breuer, Ph.D.* (*Computer Science*); Tsen-Chung Cheng, Sc.D.; John Choma, Jr., Ph.D.*; P. Daniel Dapkus, Ph.D.; Michel Dubois, Ph.D. (*Physics*); Jack Feinberg, Ph.D. (*Physics*); Robert M. Gagliardi, Ph.D.; Jean-Luc Gaudiot, Ph.D.; Seymour Ginsburg, Ph.D. (*Computer Science*); Solomon W. Golomb, Ph.D. (*Mathematics*); Martin Gundersen, Ph.D. (*Physics*); Robert W. Hellwarth, Ph.D. (*Physics*); Ellis Horowitz, Ph.D. (*Computer Science*); Kai Hwang, Ph.D. (*Computer Science*); Petros Ioannou, Ph.D.; Edmond Jonckheere, Ph.D.; Robert Kalaba, Ph.D. (*Biomedical Engineering and Economics and Speech Science and Technology*); Thomas Katsouleas, Ph.D.; Chung-Chieh Kuo, Ph.D.; Hans H. Kuehl, Ph.D.*; P. Vijay Kumar, Ph.D.; Richard Leahy, Ph.D.* (*Biomedical Engineering, Radiology*); Anthony F. J. Levi, Ph.D.; William C. Lindsey, Ph.D.; Vasilis Z. Marmarelis, Ph.D. (*Biomedical Engineering*); Jerry M. Mendel, Ph.D.; Ramakant Nevatia, Ph.D. (*Computer Science*); Chrysostomos L. Nikias, Ph.D.; George P. Papavassilopoulos, Ph.D.; Alice C. Parker, Ph.D.; V. Prasanna, Ph.D.; Aristides Requicha, Ph.D. (*Computer Science*); Michael J. Safonov, Ph.D.; Steven B. Sample, Ph.D.; Alexander A. Sawchuk, Ph.D.; Robert A. Scholtz, Ph.D.; John Silvester, Ph.D.; William H. Steier, Ph.D.; William G. Wagner, Ph.D. (*Physics*); Charles L. Weber, Ph.D.; Alan Willner, Ph.D.; Curt F. Wittig, Ph.D. (*Chemistry and Physics*); Stanley M. Yamashiro, Ph.D. (*Biomedical Engineering*); Zhen Zhang, Ph.D.

Associate Professors: Sandeep Gupta, Ph.D.; Keith Jenkins, Ph.D.; Eun Sok Kim, Ph.D.; Bart Kosko, Ph.D.; Richard Nottenburg, Ph.D.; Massoud Pedram, Ph.D.*; Timothy Pinkston, Ph.D.; Aluizio Prata, Jr., Ph.D.*; Armand R. Tanguay, Jr., Ph.D. (*Materials Science*)

Assistant Professors: Peter Beerel, Ph.D.; Joâo Hespanha, Ph.D.; Ahmed Helmy, Ph.D.; Keith M. Chugg, Ph.D.; Christos Kyriakakis, Ph.D.; Daniel C. Lee, Ph.D.; Gerard Medioni, Ph.D. (*Computer Science*); Won Namgoong, Ph.D.; John O'Brien, Ph.D.; Antonio Ortega, Ph.D.

Adjunct Professors: Paul L. Feintuch, Ph.D.; Lloyd Griffiths, Ph.D.; Kirby Holte, Ph.D.; Sukhan Lee, Ph.D. (*Computer Science*); Virendra N. Mahajan, Ph.D.; Mostafa Shiva, Ph.D.; Trieu-Kien Truong, Ph.D.; Monte Ung, Ph.D.

Adjunct Associate Professors: James Ellison, Ph.D.; Bayesteh Ghaffary, Ph.D.; Srinivasiengar Govind, Ph.D.; Alan Kost, Ph.D.; Ram C. Mukherji, M.S.; Gandhi Puvvada, M.S.; Edgar Satorius, Ph.D.; Keith Soo Hoo, Ph.D.; Ali A. Zahid, M.S.

Adjunct Assistant Professors: Douglas Bender, Ph.D.; Serge Dubovitsky, Ph.D.; Lute Maleki, Ph.D.; Toyone Mayeda, M.S.

Research Professors: Elliot I. Axelbrand, Ph.D.; Milton Birnbaum, Ph.D.

Research Associate Professor: Keith L. Price, Ph.D. (*Computer Science*)

Senior Lecturer: Kian Kaviani, Ph.D.

Instructor in Electrical Engineering: Joe Ed Baker, Engr.

Emeritus Professors: Clarence Crowell, Ph.D. (*Materials Science*); Murray Gershenzon, Ph.D.* (*Materials Science*); Kurt Lehovec, Ph.D. (*Materials Science*); Jack Munushian, Ph.D.; Eberhardt Rechtin, Ph.D. (*Industrial and Systems Engineering and Aerospace Engineering*); Irving S. Reed, Ph.D. (*Electrical Engineering*); Jan Smit, Ph.D. (*Materials Science*); William G. Spitzer, Ph.D. (*Physics and Materials Science*); Lloyd Welch, Ph.D. (*Electrical Engineering*); David B. Wittry, Ph.D. (*Materials Science*)

Emeritus Instructor: Sydney A. Wielin, B.S.

*Recipient of university-wide or school teaching award.

Electrical Engineering Honor Society: Eta Kappa Nu

Degree Requirements

Program Goals

The undergraduate programs in electrical engineering have the following objectives:

(1) Graduates will have the proficiency in mathematics, science, and engineering necessary to apply these principles effectively to the solution of problems encountered in modern electrical engineering practice.

(2) Graduates will have the preparation to compete effectively in the current world of rapid technological innovation as well as to become leaders in industrial, academic and governmental environments.

(3) Students have the opportunity to tailor their undergraduate plan of study to provide the preparation necessary either to embark immediately into professional practice or to engage in graduate level studies in such diverse areas as engineering, computer science, medicine, multimedia, law, business or music.

(4) Graduates will have the capability to model, analyze and design practical systems or components to meet desired economic and technical requirements and specifications.

(5) Graduates will have an understanding of the importance of high ethical and professional standards as well as the importance of engineering issues, decisions and solutions in a global, environmental and societal context.

(6) Graduates will have the capabilities and communication skills to function effectively as individuals or as members of multidisciplinary teams in an environment of rapid technological change and global competition.

(7) Graduates will have the background necessary to design and conduct laboratory experiments using modern, up-to-date equipment and techniques, and to analyze and interpret the data.

Bachelor of Science in Electrical Engineering

The requirement for the degree is 131 units. A cumulative scholarship average of C (2.0) is required for: (a) all courses taken at USC; (b) all courses taken within the Department of Electrical Engineering; (c) all upper division courses taken within the Department of Electrical Engineering. See also the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL CHEM 115aL	General Chemistry, or Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
CSCI 101L	Fundamentals of Computer Programming	3
EE 105	Introduction to Electrical Engineering	3
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
General education		4
		18

SECOND YEAR, FIRST SEMESTER		UNITS
EE 101	Introduction to Digital Logic	3
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		15

SECOND YEAR, SECOND SEMESTER		UNITS
EE 202L	Linear Circuits	4
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
Electives	See requirements for graduation	5
		17

THIRD YEAR, FIRST SEMESTER		UNITS
EE 301a	Introduction to Linear Systems	3
EE 364	Introduction to Probability and Statistics for Electrical Engineering	3
MATH 445	Mathematics of Physics and Engineering II	4
Electives	See requirements for graduation	3
WRIT 340	Advanced writing	3
		16

THIRD YEAR, SECOND SEMESTER		UNITS
EE 330	Electromagnetics I	3
ISE 460 BUAD 301	Engineering Economy, or Technical Entrepreneurship	3
Electives	See requirements for graduation following	7
General education		4
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
Electives	See requirements for graduation following	12
General education		4
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
Electives	See requirements for graduation following	16
		16

*Taken concurrently.

**Satisfies general education Category III.

Requirements for Graduation: Engineering Electives

All elective courses are to be 200-level or above. Engineering electives are to be chosen from the courses listed under entry-level electives, areas of specialization, non-EE engineering science elective and EE design electives.

Entry-Level Electives

The entry-level courses listed under three of the four following topical areas are required:

Communication, Control and Signal Processing: EE 241 (3), EE 301b (3)
Computer Engineering: EE 102L (2), EE 357 (3)
Electromagnetics and Energy Conversion: EE 370 (3), EE 470 (3)
Electronic Devices and Circuits: EE 338 (3), EE 348L (4)

Areas of Specialization

Courses in at least one of the 13 areas of specialization listed below are required:

Communication, Control and Signal Processing
Control Systems (take 3): EE 401 (3), EE 454L (4/CD*), EE 482 (3)
Systems (take 3 of 4): EE 434L (4/CD*), EE 467x (3), EE 482 (3), EE 483 (3)
Digital Signal Processing: EE 434L (3/CD*), EE 469, EE 483 (3)
Communication Networks (take 3 of 4): EE 450 (3), EE/CS 455x (4), EE 467x (3), CS 402x (3)

Modern Communication Systems: (take 3 of 4) EE 401 (3), EE 447L (4/D**), EE 450 (3), EE 467x (3)
Robotics: EE 454L (4/CD*), EE 482 (3), CS 445 (3).

Computer Engineering
Computer Architecture and Organization: EE 454L (4/CD*), EE 457x (3), EE 459L (3/CD*)
Hardware/Software (take 3 of 4): CS 402x (3), EE/CS 455x (4), EE 454L (4/CD*), EE 457x (3)
Computer Networks (take 3 of 4): CS 402x (3), EE/CS 455x (4), EE 450 (3), EE 457x (3).

Electromagnetics and Energy Conversion
Energy Conversion (take 3 of 4): EE 440 (3), EE 442 (3), EE 443 (3), EE 444L (4/D**)
Lasers: EE 471 (3), EE 472 (3), EE 473L (3/D**).

Electronic Devices and Circuits
Electronic Circuits (take 3 of 4): EE 447L (4/D**), EE 448 (3/D**), EE 478L (4/CD*), EE 479L (4/D**)
Integrated Circuits: EE/MS 438L (3/D**), EE 448 (3/D**), EE 477L (4/CD*).

*CD — Capstone Design Elective
**D — Design Elective

Non-EE Engineering Science Elective
At least one elective must be a non-EE engineering science elective, either from the list below: CE 205, 225, 309, 325; CHE 472; ME 201, 310, 452, 453; or others by special advisor approval.

EE Design Electives
At least three courses must be taken from the following list of design courses: EE 402, 434L*, 438L, 444L, 448, 447L, 454L*, 459L*, 473L, 477L*, 478L*, 479L, including one of the asterisked capstone design courses.

Bachelor of Science in Electrical Engineering (Computers)
The Bachelor of Science in Electrical Engineering (Computers) is earned by successfully completing the normal requirements for the Bachelor of Science in Electrical Engineering with the following courses chosen as EE electives: EE 454L; CSCI/EE 455x; EE 457x; EE 478L.

Bachelor of Science in Computer Engineering and Computer Science
See the listing under Computer Engineering, page 495.

Bachelor of Science in Electrical Engineering (Manufacturing Engineering)
If a student chooses six courses (9 to 18 units) from a prescribed program, he or she may graduate with the special designation Area of Emphasis in Manufacturing Engineering on the transcript. Details are given under Manufacturing Engineering on page 524.

Minor in Multimedia and Creative Technologies
See listing under Multimedia and Creative Technologies, page 533.

Minor in Music Recording
A minor in music recording is offered through the USC Thornton School of Music to provide undergraduate students with the background necessary to enter the field of recording engineering and to familiarize them with the design needs of modern recording equipment. The minor is recommended to electrical engineering majors with extensive musical training who would like to combine their technical and musical abilities while learning the engineering applications of physical and mathematical principles to the art of music recording. See the listing under the School of Music, page 665.

Master of Science in Electrical Engineering
A minimum grade point average of 3.0 must be earned on all course work applied toward the master's degree in electrical engineering. This average must also be achieved on all 400-level and above course work attempted at USC beyond the bachelor's degree. Transfer units count as credit (CR) toward the master's degree and are not computed in the grade point average.

In addition to the general requirements of the School of Engineering, the Master of Science in Electrical Engineering is also subject to the following requirements: (1) a total of at least 27 units is required; (2) every course for graduate credit requires prior written advisor approval recorded each semester on the study plan in the student's department file; (3) no more than nine units at the 400 level may be counted toward the degree — the remaining units must be taken at the 500 or 600 level; (4) at least 18 units must be taken in electrical engineering, those not in EE are subject to written advisor approval and must be technical in nature; (5) to achieve a degree of breadth in their program, students are encouraged to take two technical courses outside their area of specialization but within EE; (6) at least 21 of the 27 units must be taken in the School of Engineering; (7) units to be transferred (maximum four with advisor approval) must have been taken prior to taking classes at USC — interruption of residency is not allowed.

The aerospace controls option is available as an area of emphasis for MSEE students interested in learning to apply innovative control techniques to aerospace control problems. In addition to 18 approved units of electrical engineering courses, students in this option will take at least three of the following aerospace and mechanical engineering courses: ME 453 Engineering Dynamics (3); AE 512 Aerodynamics of Wings and Bodies (3); AE 515ab State Space for Aeronautical Engineers (3-3); AE 516ab Flight Vehicle Stability and Control (3-3); AE 525ab Engineering Analysis (3-3); ME 553ab Advanced Analytical Mechanics (3-3); AE 580 Orbital Mechanics (3).

Master of Science in Electrical Engineering (Computer Networks)
Under the computer networks option students must satisfy the MSEE requirements with the exception that only 15 units of EE are required and the following courses must be included in the program: EE/CSCI 450; EE/CSCI 465 or EE 549; CSCI 402; CSCI 555 or CSCI 558L; CSCI 551; EE 550 or EE 555; EE 557 or EE 554. Students who can demonstrate that they have already taken these courses (or equivalent) may be waived out of the requirement by memo from a faculty advisor. All courses must be approved by a faculty advisor. A list of suggested electives is available from the department office.

Master of Science in Electrical Engineering (Multimedia and Creative Technologies)
See listing under Multimedia and Creative Technologies, page 533.

Master of Science in Systems Architecture and Engineering
See the listing under Systems Architecture and Engineering, page 538.

Master of Science in Electrical Engineering (VLSI Design)
The Master of Science in Electrical Engineering (VLSI Design) is earned by successfully completing the normal requirements for the Master of Science in Electrical Engineering, with the following additional required courses: EE 533a; 577a; 577b or 533b; 552 and 582. If a student chooses to take EE 533b *as well* as EE 577b, the student may *either* count EE 533b as one of the courses for Area 2 or EE 577b as one of the courses for Area 1 or Area 3.

The students must also take three courses from one of the following areas and one course from a second area:

Area 1: CSCI 455x, EE 577b (see above), 658, 680 and 681.
Area 2: EE 448, 504L, 533b (see above), 536, 537 and 630.

Area 3: CSCI 455x, CSCI 570, EE 557, 577b (see above), 597, 659, 677.

With explicit approval of a faculty advisor, EE 599 Special Topics and/or 3 units of EE 590 Directed Research may be used to meet requirements for any of the approved areas.

The remaining courses must be technical electives approved by the advisor, and can including the following: EE 501, 502, 504L, 506, 532, 540, 554, 560L, 590, 601 and 677.

Bachelor of Science and Master of Science in Electrical Engineering
Students who have demonstrated exceptional academic success have the opportunity to earn both bachelor's and master's degrees in an accelerated degree program. This program allows students to earn both degrees in five years.

Admission
Admission is available to freshmen or continuing students enrolled in the Bachelor of Science in Electrical Engineering program. Freshman admission requirements are: minimum 3.8 GPA (A = 4.0) and SAT score of 1420. Continuing students: minimum 3.5 GPA and more than 20 units completed in residence. Applications are available from the Engineering Student Affairs Office, Olin Hall 106.

Curriculum Requirements
Students must meet all requirements for both the Bachelor of Science in Electrical Engineering and Master of Science in Electrical Engineering degrees. A total of 131 units is required for the Bachelor of Science degree. Undergraduate 400-level course work beyond 128 units may be applied toward the Master of Science degree. No more than nine units at the 400 level may be counted toward master's degree requirements. A total of 155 units is required for the dual degree program. Students must maintain a 3.0 grade point average or higher at all times to remain in this program.

Second Master's Degree
A graduate student who already holds a master's degree from USC or another accredited engineering school may apply up to four units toward a second master's degree with the permission of the chair of the major department. All credit, including the transferred units, must be earned within seven calendar years.

Engineer in Electrical Engineering
Requirements for the Engineer in Electrical Engineering are the same as those listed under Engineer Degree, except that both areas of concentration must be in electrical engineering.

Doctor of Philosophy in Electrical Engineering
The Doctor of Philosophy with a major in Electrical Engineering is awarded in strict conformity with the general requirements of the USC Graduate School. See general requirements for graduate degrees. Departmental requirements for this degree consist of a concentrated program of study and research and a dissertation. Each student wishing to undertake a doctoral program must first be admitted to the program and then take the screening examination. This examination will emphasize comprehension of fundamental material in one of the 13 specialized areas of electrical engineering listed below. Listed under each area are courses offered by the Department of Electrical Engineering which will provide basic background for the examination and partial preparation for the dissertation. Not all courses listed are required for preparation for the screening examination in any specific area. Consult a separately published guide, available from the department office, for more information concerning examination content and scheduling. Further guidance concerning the full completion of courses, including those given outside the department, which are recommended for preparation for the dissertation, can be obtained from the faculty in each technical area.

Major Fields in Electrical Engineering — Electrophysics
Students may major in the following fields: Electromagnetics-EE 570ab, 571ab, 572ab, 573ab, 575, 576, 578, 604; Plasma Science-EE 539, 570ab, 572ab; Power and Machinery-EE 510, 511, 512, 513, 514, 521, 524, 525, 526, 527, 528, 620, 621; Quantum Electronics-EE 529, 530, 531, 532, 539, 540; Solid State-EE 501, 502, 504L, 506, 507, 508, 533, 537, 601, 602, 604, 606, 607, 609; Integrated Circuits-EE 471, 501, 504L, 506, 533, 536, 537, 540, 569, 577, 585, 601, 602, 604, 605, 606, 630; Optics-EE 529, 530, 531, 532, 539, 540, 559, 566, 569, 589, 629ab, 642, 669.

Major Fields in Electrical Engineering — Systems
Students may major in the following fields: Biomedical Engineering and Biomathematics-EE 591ab, 593; Communication Theory-EE 535, 538, 550, 551, 562ab, 563, 564, 565ab, 566, 567, 568, 569, 583, 595, 663, 664, 666, 667, 669; Computer Engineering-EE 541, 545, 547, 548, 549, 550, 552, 553, 554, 555, 557, 560, 561, 574, 577ab, 578, 582, 597, 649, 650, 653, 656, 657, 658, 677, 680, 681 (see program listing for the Master of Science in Computer Engineering); Intelligent Systems-EE 559, CSCI 561, CSCI 574; Signal Processing-EE 522, 559, 562a, 566, 569, 583, 586L, 589, 596, 668, 669, 683, 689; Systems and Controls-EE 541, 544, 553, 563, 585, 586, 587, 588, 593, 684, 685.

Courses of Instruction

ELECTRICAL ENGINEERING (EE)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

101 Introduction to Digital Logic (3, FaSp) Boolean algebra; number systems; binary arithmetic; codes; gates; Boolean expressions; Boolean switching function synthesis; iterative arrays; sequential machines; state minimization; flip/flops; sequential circuits; simple processors.

102L Introduction to Digital Circuits (2, FaSp) Practical digital design using MSI/SSI TTL devices; practical aspects and specifications, open-collector/three-state outputs, timing and triggering; logical analyzers; finite state controllers; lab experiments; digital logic simulation. *Prerequisite:* EE 101.

105 Introduction to Electrical Engineering (3, Sp) Gateway to the majors in Electrical Engineering. An overview of modern electrical engineering: communications, computers, circuits, components, controls, electromagnetics, microelectronics; principles of commercial products such as FAX, modem, copier, CD-ROM, ATM networks.

202L Linear Circuits (4) Lumped circuit elements; network equations; zero-input and zero-state responses; sinusoidal steady-state analysis; impedance; resonance; network functions; power concepts; transformers; Laplace transforms. *Prerequisite:* PHYS 152*L*; *corequisite:* MATH 245.

241 Applied Linear Algebra for Engineering (3, FaSp) Introduction to the theory of matrices, vector spaces, least-squares approximation and MATLAB. Applications to communications, control and signal processing. *Prerequisite:* MATH 126.

301ab Introduction to Linear Systems (3-3, FaSp) *a:* Representation and analysis of linear time-invariant systems for the continuous time case. Convolution, Fourier series and transform, Laplace transform, controls and communications applications. *Prerequisite:* EE 202; *corequisite:* MATH 445. *b:* Discrete-time signals and systems, including difference equations, z-transforms, discrete-time Fourier series and transforms, sampling, filtering, digital control and modulation; state-variable models; uncertainty. *Prerequisite:* EE 301*a*; *corequisite:* EE 364.

302L Physical Optics (4, Sp) Wave nature of light, diffraction, interference, polarization, coherence, double refraction, optical activity, electro- and magneto-optics, absorption, scattering, dispersion, line spectra, laser phenomena. Lecture, 3 hours; discussion, 1 hour; laboratory, 3 hours. *Prerequisite:* PHYS 153*L* or PHYS 162*L*.

320x Digital Media Basics for Multimedia (3, FaSp) Digital media basics for creating multimedia applications including analog and digital representation, media editing, interface construction, CD ROM and network delivery. Not available for degree credit for engineering or computer science majors. *Corequisite:* ITP 210.

321 Introduction to Integrated Media Systems (3) Fundamental principles of multimedia signal processing; application to digital audio and video processing; human computer interface considerations; immersive audio and video system design considerations. (Duplicates credit in EE 320.)

326Lx Essentials of Electrical Engineering (4) Network analysis and theorems; transient analysis; transformers; semiconductor physics and circuits; power amplifiers, modulation and demodulation, and pulse, digital, and switching circuits. Introduction to instrumentation. Not available for credit to electrical engineering majors. *Prerequisite:* PHYS 152*L*, MATH 126.

327x Digital Electronics (3) Linear passive circuits; pulse and digital circuits, timing; MOS and CMOS FETs; interface circuits, standards; transmission line theory of pulses; problems of high speed circuits. Not available for credit to electrical engineering majors. *Prerequisite:* EE 326*Lx*.

330 Electromagnetics I (3, FaSp) Basic static and dynamic electromagnetic field theory and applications; electrostatics, magnetostatics, Maxwell's equations, energy flow, plane waves incident on planar boundaries, transmission lines. *Prerequisite:* EE 202*L*, MATH 445, PHYS 152*L*.

338 Physical Electronics (3) Semiconductor device characteristics and applications. Physical models of electronic conduction in solids, p-n junctions, bipolar and field effect transistors and other solid state devices. *Prerequisite:* EE 202*L*, PHYS 152*L*.

348L Electronic Circuits (4, FaSp) Basic analog and digital circuit design using Bipolar Junction Transistors, Field Effect Transistors and integrated circuits. *Prerequisite:* EE 338.

357 Basic Organization of Computer Systems (3, FaSpSm) Organization and operation of the processor, memory and I/O of a minicomputer at the machine language level; assembly language programming; data representation and computer arithmetic. *Prerequisite:* EE 101, EE 102, and a high level programming language.

364 Introduction to Probability and Statistics for Electrical Engineering (3, FaSp) Introduction to concepts of randomness and uncertainty: probability, random variables, statistics. Applications to digital communications, signal processing, automatic control, computer engineering. *Prerequisite:* MATH 245.

370 Electromechanics (3) Ferromagnetism and transformers. Energy conversion in singly and multiply excited systems. Concepts in rotating machinery analysis. Direct energy conversion. *Prerequisite:* EE 330.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

401 Transform Theory for Engineers (3, FaSp) Complex variables, Cauchy Riemann conditions, contour integration and residue theory; Fourier transform; Laplace transform; sampling theory. Discrete time filters, discrete and fast Fourier transform. *Prerequisite:* EE 301*a* and MATH 445.

402 Design of Analog and Digital Filters (3, Fa) Frequency domain design of passive and active analog filters. Ladder networks. Filter approximations. Z-transform technique. Design and realization of IIR and FIR digital filters. *Prerequisite:* EE 301*a*.

434L Digital Signal Processing Design Laboratory (4, Fa) Experiments and design project in digital signal processing (e.g., real-time DSP, acoustics, video) including: systems specification, preliminary analysis, trade-off studies, implementation, presentation. *Prerequisite:* EE 483 and departmental approval.

437 Fundamentals of Solid State (3) (Enroll in MASC 437)

438L Processing for Microelectronics (3) Applications and electrical evaluation of selected processes used in electronic microfabrication. Duplicates credit in former MASC 438*L*. *Prerequisite:* EE 338.

439 Principles of Semiconductor Processing (3) (Enroll in MASC 439)

440 Rotating Electric Machinery (3) Basic concepts of machine performance; polyphase synchronous and induction machines; fractional horsepower AC motors, self-synchronous motors and systems; and dynamics of electromechanically coupled systems. *Prerequisite:* EE 370.

441 Applied Linear Algebra for Engineering (3, FaSpSm) Introduction to linear algebra and matrix theory and their underlying concepts. Applications to engineering problems. *Prerequisite:* MATH 445.

442 Direct Energy Conversion (3) Fundamentals of direct energy conversion methods. Principles governing conversion by chemical, thermionic, thermoelectric, nuclear, and gas dynamic processes. *Prerequisite:* PHYS 152*L*, MATH 226.

443 Introduction to Power Systems (3) Components of power systems. Analysis techniques in electrical power generation transmission and utilization. Environmental and economic considerations in system operations and planning. *Recommended preparation:* EE 370.

444L Introduction to High-Efficiency Power Conversion (4) Linear and switching power converters and inverters; transformers, inductors, regulators, thermal design, power rectifiers and transistors, filters, current limiting, overvoltage protection, integrated circuits. Laboratory. *Prerequisite:* EE 348*L*.

445 Introduction to Robotics (3) (Enroll in CSCI 445)

447L Mixed Signal Electronic Circuits (4) Application of solid-state electronic devices to the design of linear and mixed-signal systems. Laboratory experiments and projects involving the design of electronic hardware. *Prerequisite:* EE 348*L*.

448 Electronic Circuits II (3) Fundamental network and semiconductor device modeling theories applied to the design and computer simulation of wideband analog and high-speed digital integrated circuits. *Prerequisite:* EE 348*L*.

450 Introduction to Computer Networks (3) Network architectures; layered protocols, network service interface; local networks; long-haul networks; internal protocols; link protocols; addressing; routing; flow control; higher level protocols. *Prerequisite:* junior standing.

454L Introduction to Systems Design Using Microprocessors (4, FaSpSm) Operation and timing of 8-bit microprocessors; design of microprocessor-based systems; 16-bit microprocessors; bit sliced microprocessors. *Prerequisite:* EE 102*L* and EE 357.

455x Introduction to Programming Systems Design (4) (Enroll in CSCI 455*x*)

457x Computer Systems Organization (3, FaSpSm) Register transfer level machine organization; CPU data paths and control; micro-programming; timing, simple arithmetic units; basic I/O organization; design using register transfer languages. Not available for graduate credit to computer science majors. *Recommended preparation:* EE 357, EE 102*L*.

459L Senior Design Project (3, Sp) Design, implementation and test of a computer hardware project; architecture, I/O interfaces, application specific hardware; presentation and demonstration. *Prerequisite:* EE 454*L* or EE 457*x*.

460 Introduction to Artificial Intelligence (3) (Enroll in CSCI 460)

464 Probability Theory for Engineers (3, FaSpSm) Axiomatic foundations of probability, random variables, Gaussian and Poisson distributions, functions of a random variable. Gaussian random vector, functions of several random variables; sequences of random variables. *Prerequisite:* EE 301*a* and MATH 445.

465 Probabilistic Methods in Computer Systems Modeling (3, Fa) Review of probability; random variables; stochastic processes; Markov chains; and simple queueing theory. Applications to program and algorithm analysis; computer systems performance and reliability modeling. *Prerequisite:* MATH 407.

467x Introduction to Communication Systems (3) Analog and digital communication systems. Modulation (AM, FM) coding, multi-plexing, noise, error rates, spectral analysis and power. Review of satellite, HDTV, mobile and fiber-optic systems. Not available for degree credit to students in the Communication Theory track in the Ph.D. in Electrical Engineering program. *Prerequisite:* EE 301*a*.

469 Introduction to Digital Media Engineering (3) Fundamentals of digital media representation, for audio, images and video signals. Sampling; Fourier and z-transforms; FFT; filter design; image segmentation, image and video compression standards. *Prerequisite:* EE 301*a* or EE 321; EE 364 or MATH 407.

470 Electromagnetics II (3) Dynamic field theory and elementary solutions to Maxwell's equations. Introduction to propagation and radiation of electromagnetic fields. *Prerequisite:* EE 330.

471 Applied Quantum Mechanics for Engineers (3) Introductory quantum mechanics and applications. Schrodinger equation, atomic and molecular processes, time-dependent perturbation theory. Applications to lasers, solid state demos and gaseous devices. *Prerequisite:* EE 330 or graduate standing.

472 Introduction to Lasers and Laser Systems (3) Electric dipole transitions; traveling wave and resonant amplifiers; laser pumping and rate equations; threshold, frequency, and power output of lasers; holography; laser communication systems.

473L Lasers and Optics Laboratory (3) Introductory design/research laboratory in lasers and optics, which typically includes fiber optics, photonics, electro-optics, optical sensors, optical communication, optical signal processing and computing. *Corequisite:* EE 470 or consent of instructor.

476 Chemical Engineering Materials (3, Sp) (Enroll in CHE 476)

477L MOS VLSI Circuit Design (4, Fa) Analysis and design of digital MOS VLSI circuits including area, delay and power minimization. Laboratory assignments including design, layout, extraction, simulation and automatic synthesis. *Prerequisite:* EE 327 or EE 338.

478L Digital Electronic Circuit Design (4, Sp) Design of digital electronic circuits. Laboratory experiments and an extensive term project using digital hardware. *Prerequisite:* EE 348*L*.

479L Introduction to Integrated Circuit Design (4) Discussion of bipolar and MOS fabrication principles and IC layout guidelines. Discussion of broadbanded bipolar IC's and MOS circuit transient switching response. Laboratory. *Prerequisite:* EE 348*L*.

482 Linear Control Systems (3, FaSpSm) Analysis of linear control systems; continuous and sampled-data systems, various stability criteria; frequency response and root locus compensation techniques. *Prerequisite:* EE 301*a* or graduate standing.

483 Introduction to Digital Signal Processing (3, FaSp) Fundamentals of digital signal processing covering: discrete time linear systems, quantization, sampling, Z-transforms, Fourier transforms, FFTs and filter design. *Prerequisite:* EE 301*a*.

490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

499 Special Topics (2-4, max 8) Course content will be selected each semester from current developments in the field of electrical engineering.

500 Neural and Fuzzy Systems (3) Neural networks and fuzzy systems, including: neuron structure and dynamics, unsupervised and supervised learning, network models and architectures, network stability and learning convergence. *Recommended preparation:* EE 464.

501 Solid State (3) (Enroll in MASC 501)

502 Advanced Solid State (3) (Enroll in MASC 502)

504L Solid State Processing and Integrated Circuits Laboratory (3) Laboratory oriented with lectures keyed to practical procedures and processes. Solid-state fabrication and analysis fundamentals; basic device construction techniques. *Prerequisite:* BSEE.

505 Microelectronic Neural Networks and System Applications (3, Sp) Compact understanding of neural network paradigms; architectures and data flow for microelectronic neural processors and systems; digital-analog VLSI sensing and microrobotic control; system applications. *Prerequisite:* EE 483; *corequisite:* EE 577*a*.

506 Semiconductor Physics (3) Semiconductor bonds, crystallography, band structure assumptions, group theory, band structure results, k.p. method, quantum wells, wires and dots, superlattices, amorphous, organic semiconductors, defects, statistics, surfaces. *Prerequisite:* MASC 501.

507 Magnetic and Dielectric Properties of Materials (3) (Enroll in MASC 507)

508 Imperfections in Solids (3) (Enroll in MASC 508)

510 Symmetrical Components (3) The theory of symmetrical components and their use in power system analysis; sequence impedances of system components; other transformations and applications.

511 Transmission of Electric Power (3) Constants of overhead lines and cables. Mutual effects. Analysis of transmission systems — electrical and mechanical considerations. *Prerequisite:* EE 510.

515 High Voltage Technology (3) High voltage engineering basic concepts; theoretical, design, and practical aspects of overvoltages, travelling-waves, insulation, and aging; breakdown mechanisms; insulation coordination.

516 Electric Power Distribution (3, Irregular) Distribution system planning, load characteristics, substation, primary and secondary networks, cables and overhead conductors, voltage regulation and capacitor application, effects of industry deregulation. *Prerequisite:* EE 510; *recommended preparation:* EE 443.

518 Semiconductor Materials for Devices (3) (Enroll in MASC 518)

519 Speech Recognition and Processing for Multimedia (3) Speech production, acoustics, perception, synthesis, compression, recognition, transmission. Coding for speech, music, and CD-quality. Feature extraction. Echo cancellation. Audio, visual synchronization. Multimedia, internet use. *Prerequisite:* EE 483.

520 Digital Media and Multimedia Applications (3) Multimedia systems development using digital media (including images, audio and video). Digital representation, artifacts, programming, use of current tools for creating new multimedia applications. *Prerequisite:* C/C++ programming experience; bachelor's degree in Electrical Engineering or Computer Science of consent of instructor.

521 Power Systems (3) Transmission lines; transients in power systems; control; stability. Special topics.

522 Immersive Audio Signal Processing (3, Sp) Fundamentals of digital audio signal processing, room acoustics, and psychoacoustics. Algorithms for real-time implementation of immersive audio systems for integrated media applications. *Prerequisite:* EE 301*b*; *recommended preparation:* EE 483.

524 Transients in Power Systems (3) Overvoltages during faults, voltage recovery, arcing faults, restrikes, theory of switching surges. Systems grounding, traveling waves, lightning and surge protection, insulation coordination. *Prerequisite:* EE 510.

525 Power System Protection (3) Theory of system and equipment protection, characteristics of relays, relay coordination, and system considerations. *Prerequisite:* EE 510.

526 Economic Operation of Electric Power Systems (3) Power system formulation; determination of loss coefficients and penalty factors; dispatch of thermal systems and pools; introduction to combined hydro-thermal dispatch; digital techniques. *Prerequisite:* three courses in power area.

527 Digital Techniques in Power System Analysis and Control (3) System formulations for digital studies. Topics in the application of computers to the planning, analysis, and control of power systems.

528 DC and AC-DC Power Systems (3) Discussion of high-voltage DC transmission systems. Aspects of operation, protection, construction, and economics of DC and parallel AC-DC operation. *Prerequisite:* EE 511.

529 Optics (3) Basic graduate level optics including wave optics, foundations of geometric optics, optical elements, aberration theory, Hermite-Gaussian beams, multilayer structures, and matrix techniques. *Recommended preparation:* EE 470 or graduate standing.

530 Optical Materials, Instruments and Devices (3) Anisotropic materials and devices; properties of metals; design and theory of selected optical instruments; properties of electrooptic, acoustooptic, and spatial light modulators; optical detectors. *Prerequisite:* EE 529.

531 Nonlinear Optics (3) Theory of nonlinear optical susceptibility and application to self-focusing, harmonic generation, and parametric interactions. Raman and Brillouin scattering. Coherent spectroscopy. *Prerequisite:* EE 470.

533ab Mixed-Signal VLSI Systems Design (a: 3, Fa; b: 3, Sp) *a:* Integrated-circuit fabrication; circuit modeling and simulation; basic and advanced operational amplifiers and comparators; switched-capacitor and continuous-time filters; data converters; layout techniques. *Prerequisite:* EE 447*L* or; corequisite: EE 577*a*. *b:* Mixed-signal VLSI design project; preparation of chips for fabrication; mixed-signal testing; current-mode techniques; nonlinear circuits; electrical and optical inputs; low-power design. *Prerequisite:* EE 533*a*.

534 Materials Characterization (3) (Enroll in MASC 534)

535 Mobile Communications (3) The mobile communication channel; techniques used to combat the channel; cellular communications; multiple-access techniques; example mobile communication systems. *Prerequisite:* EE 464; *recommended preparation:* EE 567 and some background in electromagnetics.

536 Integrated Circuit Analysis and Design (3) Development and application of advanced circuit theoretic concepts and computer-based device circuit models for the design of custom analog integrated circuits. *Prerequisite:* EE 348 or equivalent, as determined by instructor.

537 Survey of Modern Solid-State Devices (3) Important semiconductor devices for power supplies, amplifiers, controls, logic circuitry, computer memory, etc. Emphasis on properties of different types of devices now available. *Recommended preparation*: EE 338.

538 Spread Spectrum Systems (3) Covers the description analysis and design of Spread Spectrum Systems in military, navigation and wireless communication applications: portable, mobile, cellular and micro-cellular (PCS), including the industry standard IS-95. *Prerequisite:* EE 564; *recommended preparation:* EE 568.

539 Engineering Quantum Mechanics (3, Fa) Quantum mechanics for engineering majors who work with solid state devices, quantum electronics, and photonics. Schroedinger equation, perturbation theory, electronic and optical processes.

540 Introduction to Quantum Electronics (3) Fundamentals of light amplification; laser amplifiers and oscillators; atomic pumping; maser and laser systems; definitions of coherence; measurements in quantum electronics. *Prerequisite:* EE 470.

542 Advanced Power System Protection (3) HV and EHV Power System Protection topics: power line carriers, phase comparison, directional comparison, transfer trip, multi-terminal lines, breaker failure and generation. *Prerequisite:* EE 525.

543abL Digital Control Systems (a: 3, Fa; b: 1, Sp) *a:* Design, analysis, and implementation of digital control systems using microcomputers; Z-transform methods; frequency domain and state space approach; computational aspects; sampling and quantization. *Prerequisite:* EE 482. *b:* Modeling of real processes; design and implementation of digital control systems in the controls laboratory. (Duplicates credit in former EE 485*abL*.) *Prerequisite:* EE 543*a*.

545 Robotics (3, FaSp) (Enroll in CSCI 545)

547 Sensing and Planning in Robotics (3, Fa) (Enroll in CSCI 547)

548 Analytical Methods in Robotics (3) (Enroll in ME 548)

549 Queueing Theory for Performance Modeling (3, Fa) Review of Poisson and Markov processes; Markovian and non-Markovian queueing systems; networks of queues; priority queueing; applications of the theory to computer systems and communication networks. *Prerequisite:* EE 464.

550 Design and Analysis of Computer Communication Networks (3, Sp) Applications of stochastic modeling and optimization techniques to communication network design and analysis. Data link control; performance models; multi-access channels; routing and flow control. *Prerequisite:* EE 450; EE 549 or EE 465.

551 Principles of Radar (3, Sp) Signal propagation, reflections from targets; radar equation; detection of scintillating targets; resolution; ambiguity functions; clutter rejection; tracking radars. *Prerequisite:* EE 470; *corequisite:* EE 562*a*.

552 Logic Design and Switching Theory (3, FaSpSm) State minimization of incompletely specified sequential circuits; asynchronous sequential circuits; races; state assignments; combinatorial and sequential hazards in logic circuits. *Prerequisite:* graduate standing.

553 Computational Solution of Optimization Problems (3, Sp) Computer algorithms for system optimization. Search techniques, gradient methods, parameter optimization in control systems. Optimization with constraints; linear and nonlinear programming. Random search techniques. *Prerequisite:* EE 441.

554 Real Time Computer Systems (3, Sp) Structure of real-time computer systems; analog signals and devices; scheduling, synchronization of multiprocessors; reliability, availability; serial/parallel computations; real-time operating systems and languages; design examples. *Prerequisite:* EE 457*x* and CSCI 455*x*.

555 Broadband Network Architectures (3, FaSp) ATM and BISDN, switch designs, high speed local, campus and metropolitan area networks, lightwave and photonic networks, network management techniques, applications and gigabit testbeds. *Prerequisite:* EE 450 and EE 465.

556 Stochastic Optimization (3) Dynamic programming for discrete time stochastic dynamical systems, stochastic approximation, learning algorithms, stochastic stability, simulated annealing. *Prerequisite:* EE 562*a*.

557 Computer Systems Architecture (3, FaSpSm) Comparative studies of computer system components: the CPU, memory, and I/O; analytical modeling techniques to allow comparative evaluation of architectures; parallelism and supercomputers. *Prerequisite:* EE 457*x* and CSCI 455*x*.

558 Optical Fiber Communication Systems (3) State-of-the-art optical fiber communication systems. Emphasis on optoelectronic-device and communication-systems issues necessary to provide high-speed and/or networked optical communications. *Recommended preparation:* EE 338; basic knowledge of optics, semiconductor, and communications concepts.

559 Mathematical Pattern Recognition (3, Fa) Distribution free classification, discriminant functions, training algorithms; statistical classification, parametric and nonparametric techniques, potential functions; non-supervised learning. *Prerequisite:* EE 464; *corequisite:* EE 441.

560 Digital System Design-Tools and Techniques (3, Fa) ASIC design, FPGAs, VHDL, verilog, test benches, simulation, synthesis, timing analysis, post-synthesis simulation, FIFOs, handshaking, memory interface, PCI bus protocol, CAD tools, design lab exercises. *Prerequisite:* EE 457, EE 454*L*; *recommended preparation:* familiarity with CAD tools.

561ab Artificial Intelligence (3-3, FaSp) (Enroll in CSCI 561*ab*)

562ab Random Processes in Engineering (3-3, FaSpSm) *a*: Random vectors, sequences, and functions. Linear transformations, second moment theory, spectral densities, narrowband processes, Gaussian processes, correlation detection, linear minimum mean square error estimation. *Prerequisite:* EE 441, EE 464. *b:* Orthogonal or independent increment processes. Poisson processes. Nonlinear operations on random processes; power-law detectors. Markov chains and processes; the Fokker-Planck equation; level crossing problems. *Prerequisite:* EE 562*a*.

563 Estimation Theory (3, Fa) Parameter estimation and state estimation technique including: least squares, BLUE, maximum-likelihood, maximum a posteriori, Kalman-prediction, Kalman-filtering and Kalman smoothing and extended Kalman filtering. *Prerequisite:* EE 562*a*.

564 Communication Theory (3, FaSp) Elementary statistical design theory with applications to the design of digital communications receivers and radar receivers; signal design in digital communications.

565ab Information Theory (a: 3, Fa; b: 3, Sp) Information measures; asymptotic equipartition property; source coding theorem; noiseless coding; cryptography, channel coding theorem; rate distortion theory; Gaussian channels; multiple user source and channel theory. *Prerequisite:* EE 464; EE 565*a* before *b*.

566 Optical Information Processing (3, Fa) Coherent and incoherent optical transforming, imaging and two-dimensional information processing systems; optical image processing, spatial frequency response and filtering; optical and digital holography. *Recommended preparation:* EE 401.

567 Communication Systems (3, Fa) Analysis of communication systems operating from very low to optical frequencies. Comparison of modulation and detection methods. System components description. Optimum design of communication systems. *Prerequisite:* EE 562*a*.

568 Error Correcting Codes (3, Sp) Finite field theory; linear block codes, convolutional codes, algebraic codes; decoding methods; examples. *Prerequisite:* EE 565*a*.

569 Introduction to Digital Image Processing (3, FaSp) Image sampling, 2-D image transform, image enhancement, geometric image modification, morphologic processing, edge detection, texture analysis, image filtering and restoration. Graduate standing. *Recommended preparation:* EE 401, EE 464.

570ab Advanced Electromagnetic Theory (3-3) Static and dynamic electromagnetic field theory; solution of scalar and vector boundary value problems; Kirchhoff radiation theory; geometrical optics and geometrical diffraction theory. *Prerequisite:* EE 470.

571ab Microwave Networks (3-3) *a:* Microwave network theory for transmission lines and waveguides, discontinuities, impedance transformers, resonators, multi-junction networks, periodic structures, non-reciprocal and active devices. *Prerequisite:* EE 470. *b:* Parameter matrices, approximate design procedures for distributed networks from lumped networks, coupled lines, equivalent coupled-line circuits, Kuroda's identities, and capacitance matrix transformations. *Prerequisite:* EE 571*a*.

572ab Plasma Dynamics (3-3) Particle drifts, collision phenomena, Boltzmann and Vlasov equations, hydrodynamic equations, Coulomb interactions; waves in a cold and hot plasma, plasma oscillations, Landau damping, hydromagnetic waves.

573ab Antenna Analysis (3-3) Analysis of idealized antenna models, including the dyadic Green's function, reciprocity, aperture radiation, methods of moments, geometrical and physical optics, reflectors, arrays. *Prerequisite:* EE 470.

574 Computer Vision (3, Fa) (Enroll in CSCI 574)

575 Application of Method of Moments to Electromagnetic Problems (3) Formulations of and solutions to integral equations in electromagnetic scattering and radiation problems. *Prerequisite:* EE 570*ab*.

576 Analytical Techniques for Electromagnetic Theory (3) A study of analytical techniques commonly used in electromagnetic theory including integral transforms, asymptotic approximations, modal expansions, series transformations, function theoretic methods, and variational formulations. *Prerequisite:* EE 570*ab*.

577ab VLSI System Design (a: 3, Fa; b: 2, Sp) *a*: Integrated circuit fabrication; circuit simulation; basic device physics; simple device layout; structured chip design; timing; project chip; MOS logic; system design silicon compilers. *Prerequisite:* EE 457*x* or corequisite: EE 552; *b:* VLSI design project; preparation of chips for fabrication; testing fabricated chips; design examples; design of specific units (e.g., buses); design techniques; testability; system integration. *Prerequisite:* EE 577*a*.

578 Reflector Antennas (3) Introduction to the analytical and numerical techniques used in the analysis and design of modern reflector antenna systems, including physical optics, asymptotic techniques, shaping and feeds. *Prerequisite:* EE 470.

579 Graph and Combinatorial Algorithms (3) (Enroll in CSCI 579)

580 Optical Communications (3, Sp) Analysis and design of optical and fiber optical systems; direct detection, heterodyning, laser modulation formats; receiver analysis and fiber modeling; digital error probabilities. *Prerequisite:* EE 562*a*.

581 Sonar Signal Processing (3, Sp) Introduction to sonar medium, signal, and noise models; systems using array processing with large time bandwidth product signals; array shading, detection, classification, analysis of performance. *Prerequisite:* EE 562*a*.

582 Technical Seminar on VLSI Design (1) VLSI design topics; packaging; design; multichip modules; field-programmable gate arrays; thermal analysis; advanced technologies; fabrication; high speed circuitry; commercial CAD/CAE packages. Graded CR/NC. *Prerequisite:* EE 577*a*.

583 Adaptive Signal Processing (3, FaSp) Weiner filtering, linear prediction, method of steepest descent, stochastic gradient algorithms, recursive least-squares (RLS), fast RLS, RLS with systolic arrays, QRD-least squares methods, blind deconvolution. *Prerequisite:* EE 483, EE 562*a*.

584 Chaotic Systems (3, Fa) Logistic map, chaotic bifurcation, strange attractors, and fractals. Conservative dynamical systems and measure preserving transformations. Ergodicity. Kolmogorov-Sinai entropy. Chaotic/stochastic realization. Chaos in feedback. *Prerequisite:* EE 562*a*.

585 Linear System Theory (3, FaSpSm) Analysis of linear dynamical systems by state-space techniques; controllability, observability, stability, passivity. Application of feedback control and network synthesis. *Prerequisite:* EE 441.

586L Advanced DSP Design Laboratory (4) Real-time adaptive signal processing design projects using special purpose DSP processors. Suitable project areas include acoustics, speech, arrays, image compression and biomedical signal processing. *Prerequisite:* EE 583 or EE 569.

587 Nonlinear and Adaptive Control (3, Fa) Nonlinear systems, Lyapunov Stability, Parameter Identification, direct and indirect adaptive control for linear and nonlinear systems. Design analysis, stability, robustness and applications. Backstepping, feedback linearization. (Duplicates credit in former EE 587 and EE 685.) *Prerequisite:* EE 482, EE 585.

588 Linear Quadratic Control (3, Sp) Linear systems with quadratic cost, Riccati equations, observers, Kanman-Bucy filters, separation principle, discrete linear optimal control systems. *Prerequisite:* EE 585; *recommended preparation:* EE 482, EE 562*a*.

589 Statistical Optics (3, FaSp) Statistical methods in optical information processing. Interferometry, propagation, imaging with partially coherent light; statistics of randomly inhomogeneous media, photon counting, holography, photographic and optical detectors. *Prerequisite:* EE 566; corequisite: EE 562*a*.

590 Directed Research (1-12, FaSpSm) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

593 Multivariable Control (3, Fa) Feedback performance analysis; robustness and stability margins; sensitivity; disturbance attenuation; design tradeoffs; singular value, characteristic locus, and inverse Nyquist array design methods. *Prerequisite:* EE 482 and EE 585.

594abz Master's Thesis (2-2-0, FaSpSm) For the master's degree. Credit on acceptance of thesis. Graded IP/CR/NC.

595 Algebraic Coding Theory (3, Fa) Finite field theory; Reed Solomon codes; algebraic codes; algebraic decoding methods; examples. *Prerequisite:* graduate standing.

596 Wavelets (3, Fa) The theory and application of wavelet decomposition of signals. Includes subband coding, image compression, multiresolution signal processing, filter banks, and time-frequency tilings. *Prerequisite:* EE 483; *recommended preparation:* EE 569, MATH 570*a*.

597 Microsystems Technology for Multimedia (3, Fa) Microelectronics design technology covering applications, methods, efficient architectures, high-performance computing modules, and integration for compact image, video, text, audio compression, processing, and transmission. *Prerequisite:* EE 577*a*.

598 Expert Systems (3) (Enroll in CSCI 598)

599 Special Topics (2-4, max 9) The course content will be selected each semester to reflect current trends and developments in the field of electrical engineering.

601 Semiconductor Devices (3) Generalized device performance criteria. Charge storage, tunneling, transport and avalanche in majority, minority, and transferred carrier devices. Device interface phenomena. Noise; integration of devices. *Recommended preparation:* EE 472 or EE 537.

604 Microwave Solid State Devices (3) Interactions between fields and drifting carriers which lead to active device operation at microwave frequencies. Avalanche, transferred electron, and acoustoelectric oscillators and amplifiers; parametric interactions. *Recommended preparation:* EE 601 or EE 537.

605 Heterojunction Materials and Devices (3) Heterojunction materials systems, heterojunction theory, majority and minority carrier transport, carrier confinement, tunneling, quasi-electric fields, modulation doping, lasers detectors, solar cells, transistors and quantum wells. *Prerequisite:* EE 601.

606 Nonequilibrium Processes in Semiconductors (3) Photoconductivity, photovoltaic, and photomagnetic effects. Carriers lifetime and trapping; luminescence; hot carrier and high field effects. *Prerequisite:* MASC 501.

630 Advanced Electrical Circuit Theory (3) Systematic formulation of electrical network theory leading to generalized analysis methods. Multiport networks and electrical adjoints for sensitivity analyses. Feedback and stability theory.

642 Advanced Geometrical Optics (3) First order design of optical systems; origin of aberrations and their effects on wave propagation and imaging based on geometrical and physical optics. *Prerequisite:* EE 529.

650 Advanced Topics in Computer Networks (3, Irregular) Protocol modeling: flow and congestion control, dynamic routing, distributed implementation; broadcast communication media and multiple access protocols; local networks, satellite networks, terrestrial radio networks. *Prerequisite:* EE 549 and EE 550.

653 Multithreaded Architectures, Data-Flow Computing and Functional Programming (3, Fa) Programmability of general purpose multiprocessor systems, functional programming, data-flow and multithreaded computers, existing prototypes, fault-tolerance issues. *Prerequisite:* EE 557 or departmental approval.

657 Parallel Processing (3, FaSp) Array processors, multiprocessors, pipeline processors; data flow computers; VLSI architectures; parallel numerical and non-numerical algorithms; mapping algorithms onto computer structures. *Prerequisite:* EE 557.

658 Diagnosis and Design of Reliable Digital Systems (3, Fa) Fault models; test generation; fault simulation; self-checking and self-testing circuits; design for testability; fault tolerant design techniques; case studies. *Prerequisite:* graduate standing.

659 Interconnection Networks (3, Fa) Theory, design and analysis of interconnection networks for multiprocessor systems. Study of direct and indirect topologies, deadlock-free routing, flow control, network interfaces, optical interconnects. *Prerequisite:* EE 557.

663 Satellite Communications (3) Analysis and design of communication systems that operate via orbiting satellites. Covers hardware, performance capabilities, system design, and applications to today's satellite systems. (Duplicates credit in former CSCI 592.) *Prerequisite:* EE 562*a*; *recommended preparation:* EE 567, EE 564 and a Bachelor of Science degree in Electrical Engineering.

664 Advanced Topics in Communication Theory (3, 2 yrs, Sp) Tracking-loop theory, digital communication system design, optimal analog receivers, sequential decision theory with applications. Prerequisite: EE 562*a* and EE 564.

666 Data Communication (3, Irregular) Intersymbol interference, linear and nonlinear adaptive equalization, fading and dispersive channels diversity, AM to PM interference, spread spectrum systems. *Prerequisite:* EE 564.

667 Array Signal Processing (3, Sp) Beamforming principles, monopulse and conical-scan concepts, phased arrays, synthetic multiple beam arrays; signal processing techniques for synthetic aperture formation, adaptivity, and retro-directing. *Prerequisite:* EE 562*a*.

668 VLSI Array Processors for Signal Processing (3, Irregular) Signal processing algorithms; applications of special purpose VLSI processing architecture, systolic/wavefront arrays, VLSI DSP chips and array processors to digital signal processing and scientific computation. *Prerequisite:* EE 483.

669 Selected Topics in Digital Image Processing (3, Sp) Special topics in image processing selected from the following areas: still and video image compression, biomedical imaging and others. *Recommended preparation:* EE 464.

674ab Advanced Topics in Computer Vision (3-3, Irregular) (Enroll in CSCI 674*ab*)

677 VLSI Architectures and Algorithms (3) VLSI models; measures of area, volume and time; mapping algorithms; systolic arrays; area time tradeoffs; applications to signal and image processing problems. *Prerequisite:* EE 557.

680 Computer Aided Design of Digital Systems I (3, Sp) Synthesis; partitioning; placement; routing of digital circuits; integrated circuit design methods; simulation at the switch, gate, register transfer and system levels. *Recommended preparation:* EE 577*a*.

681 Computer-Aided Design of Digital Systems II (3) Theory and techniques for design and analysis of digital logic; specification, formal models; hardware-descriptive languages; formal verification, high level synthesis; logic synthesis. *Prerequisite:* EE 557, EE 680.

683 Modern Spectral Analysis (3, Irregular) Definitions, useful concepts and applications, conventional methods, maximum likelihood and maximum entropy methods, parametric methods, harmonic retrieval methods, introduction to higher-order spectrum. *Prerequisite:* EE 483, EE 562*a*.

689 Optical Computing Systems (3, Sp) Systems for analog, discrete and binary numerical computations on 1-D or multidimensional data; matrix-vector processors; input/output; combinational and sequential logic; interconnections; parallel optical processors. *Prerequisite:* EE 566.

690 Directed Research (1-4, max 8, FaSpSm) Laboratory study of specific problems by candidates for the degree Engineer in Electrical Engineering. Graded CR/NC.

790 Research (1-12, FaSpSm) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0, FaSpSm) Credit on acceptance of dissertation. Graded IP/CR/NC.

Environmental Engineering

Kaprielian Hall 210
(213) 740-0603
Email: civileng@mizar.usc.edu

Director: L. Carter Wellford, Ph.D.

Associate Director: Massoud Pirbazari, Ph.D.

Faculty

Professors: Joseph Devinny, Ph.D. (*Civil Engineering*); Jiin-Jen Lee, Ph.D., P.E. (*Civil Engi-*

neering)*; Massoud Pirbazari, Ph.D. (*Civil Engineering*); Teh Fu Yen, Ph.D. (*Civil Engineering*)

Associate Professor: Ronald C. Henry, Ph.D. (*Civil Engineering*)

Assistant Professor: Constantinos Sioutas, Sc.D.

Adjunct Professor: Frank R. Bowerman, M.S., P.E.

*Recipient of university-wide or school teaching award.

Bachelor of Science in Environmental Engineering
See listing on page 483, Civil Engineering.

Minor in Environmental Engineering
A minor in environmental engineering is offered for undergraduate students in various fields of engineering and natural sciences: (1) to provide them with a basic knowledge of our environment, potential causes for its deterioration, methods to prevent or mitigate environmental hazards, and the means to improve its quality at reasonable costs; and (2) to enhance their employment opportunities in the field of environmental engineering. A minimum of 20 units of coordinated courses is required for completion.

Prerequisite courses
CHEM 105aL-bL or CHEM 115aL-bL; MATH 125, 126 and 226 and PHYS 151L.

REQUIRED COURSES		UNITS
CE 443	Environmental Chemistry	3
CE 453	Water Quality Control	3
CE 463L	Water Chemistry and Analysis	3
ENE 201	Environmental Quality Control and Management: A Global Approach	4
ENE 410	Environmental Fluid Mechanics	3
ENE 428L	Air Pollution Fundamentals, or	
ENE 429	Air Pollution Control	3
ENE 495	Seminars in Environmental Engineering	1
		minimum 20

Bachelor of Science in Civil Engineering (Environmental Engineering)
See listing under Civil Engineering on page 486.

Master of Science in Environmental Engineering
See listing under Civil Engineering on page 488.

Ph.D. in Engineering (Environmental Engineering)
See listing under Civil Engineering on page 489.

Graduate Certificate in Environmental Sciences, Policy and Engineering Sustainable Cities
See the listing under Geography on page 271.

Courses of Instruction

ENVIRONMENTAL ENGINEERING (ENE)

The courses indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

201 Environmental Quality Control and Management: A Global Approach (4, Sp) Gateway to B.S. in Civil Engineering (Environmental Engineering), B.S., Environmental Engineering, and Minor in Environmental Engineering. Fundamental concepts of environmental science and engineering. Pollution control and remediation for air, water and soil. Pollution remediation for developing countries.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

400 Environmental Engineering Principles (3, FaSp) Analysis of water, air, and land pollution, including hazardous waste and engineering of mitigation measures. Water and waste water treatment analysis. *Prerequisite:* departmental approval.

410 Environmental Fluid Mechanics (3, FaSp) Equation of motion; continuity, momentum, energy principles; dimensional analysis, similitudes; groundwater flows; transports in conduits and channels; mixing, dispersion in environments; manifold diffusers; hydraulic transients. (Duplicates credit in CE 309 and AE 309.) *Prerequisite:* MATH 226.

428 Air Pollution Fundamentals (3, Sp) Air pollution effects on man, vegetation, materials; pollutant sampling and analysis; air quality standards and criteria; meteorological factors and dispersion modeling. *Prerequisite:* senior standing.

429 Air Pollution Control (3, Fa) Emission surveys; engineering controls of aerosols and gaseous contaminants at emission sources, disposition of contaminants. Field trips. *Prerequisite:* senior standing.

443 Environmental Chemistry (3) (Enroll in CE 443)

453 Water Quality Control (3) (Enroll in CE 453)

463L Water Chemistry and Analysis (3) (Enroll in CE 463*L*)

465 Water Supply and Sewerage System Design (3) (Enroll in CE 465)

486 Solid and Hazardous Waste Engineering (3, Fa) Engineering design of solid and hazardous waste facilities such as waste minimization, secured landfill, and hazardous waste treatment. *Prerequisite:* ENE 400.

495 Seminars in Environmental Engineering (1, FaSp) Hazardous waste management, biodegradation of environmental pollutants, groundwater problems, waste minimization, energy resources, and air pollution control.

501 Waste Minimization and Resource Recovery (3, Sm) Engineering of hazardous waste reduction and minimization; application of material and energy resource recovery concepts; reduction of hazardous and nonhazardous waste disposal. *Prerequisite:* graduate standing.

502 Environmental and Regulatory Compliance (3, FaSp) Federal and state environmental laws; environmental impact assessment techniques; permitting for industrial facility construction and operation. *Prerequisite:* graduate standing.

503 Microbiology for Environmental Engineers (3) (Enroll in CE 503)

504 Solid Waste Management (3) (Enroll in CE 504)

505 Energy and the Environment (3, Fa) Environmental effects of energy development using fossil and fissile fuels, geothermics, photosynthesis, and other sources. Relationship of elemental cycles to the life supporting systems.

506 Ecology for Environmental Engineers (3, Sp) The role of environmental engineering in maintaining stability of freshwater, marine, and terrestrial ecosystems; macroscopic plant and animal forms as indicators of water quality.

513L Instrumental Methods for Environmental Analysis (3) (Enroll in CE 513*L*)

514ab Advanced Sanitary Engineering Design (3-3) (Enroll in CE 514*ab*)

516 Hazardous Waste Management (3, Fa) Standards and regulations for the management of hazardous waste: identification, transportation, monitoring, storage, treatment, and disposal practices. *Prerequisite:* departmental approval.

517 Industrial and Hazardous Waste Treatment and Disposal (3) (Enroll in CE 517)

523 Physical Processes of Environmental Engineering (3) (Enroll in CE 523)

526 Environmental Pollutants: Monitoring and Risk Assessment (3, Sp) Gaseous and particulate air pollutants, their measurement and instrumentation methods, and their effects on the environment and human health; studies on toxicity and risk assessment of selected pollutants.

553 Chemical and Biological Processes in Environmental Engineering (3) (Enroll in CE 553)

560 Environmental Aspects of Oil and Gas Production (3, Sp) Environmental aspects of drilling for and producing oil and gas, and the necessary safety practices. Attention is given to the urban areas.

563 Chemistry and Biology of Natural Waters (3) (Enroll in CE 563)

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

594abz Master's Thesis (2-2-0) Credit on acceptance of thesis. Graded IP/CR/NC.

596 Chemical Reactions in the Atmosphere (3, 2 years, Fa) Chemical reactions and scavenging processes important in urban air pollution. Effects of solar irradiation on vehicle exhaust gases, oxides of nitrogen and sulfur.

790 Research (1-12) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Industrial and Systems Engineering

Ethel Percy Andrus
Gerontology Center 240
(213) 740-4893
FAX: (213) 740-1120
Email: efelina@usc.edu

Chair: F. Stan Settles, Ph.D.

Faculty

David Packard Chair in Engineering: Stephen C-Y Lu, Ph.D. (*Aerospace and Mechanical Engineering*)

Professors: Ralph Keeney, Ph.D. (*Information and Operations Management*); Randolph Hall, Ph.D.; Behrokh Khoshnevis, Ph.D.; F. Stan Settles, Ph.D.

Associate Professors: Maged Dessouky, Ph.D.*; Najmedin Meshkati, Ph.D. (*Civil Engineering*); Mansour Rahimi, Ph.D.

Assistant Professors: Satish Bukkapatnam, Ph.D.; Kurt Palmer, Ph.D.

Adjunct Professors: George Friedman, Ph.D.; Michael Mann, Ph.D.

Adjunct Associate Professors: Geza P. Bottlik, Engineer; Thomas J. Higgins, Ph.D.; Jeffrey Smith, Ph.D.

Research Professors: Mohamed I. Dessouky, Ph.D.; Peter Will, Ph.D.

Emeritus Professors: Clinton J. Ancker, Jr., Ph.D., P.E.; Ward Edwards, Ph.D. (*Psychology*); Gerald A. Fleischer, Ph.D., P.E.; Antranig V. Gafarian, Ph.D., P.E.; Homer H. Grant, M.S.; Gerald Nadler, Ph.D., P.E. (*IBM Chair in Engineering Management*); Eberhardt Rechtin, Ph.D. (*Electrical Engineering/Systems*)

*Recipient of university-wide or school teaching award.

Honorary Societies

Alpha Pi Mu

Alpha Pi Mu is the industrial engineering honor society. Qualifications for election are: juniors in the upper one-fourth of their class, seniors in the upper one-third of their class and graduate students recommended by the department chair. The advisor is Satish Bukkapatnam, Assistant Professor, (213) 740-9549.

Omega Rho

Omega Rho is the operations research honor society to recognize academic excellence in operations research and encourage study of operations research, management science and closely associated disciplines. Election is by nomination only during the spring semester. The advisor is Maged Dessouky, Associate Professor, (213) 740-4891.

Degree Requirements

Program Goals

Industrial and Systems Engineering provides a university-based framework for the practice of industrial and systems engineering. Specifically, the goals are to prepare the graduate to:

(1) Immediately embark on a professional and ethical practice.

(2) Achieve technical proficiency in industrial and systems engineering.

(3) Engage in a lifetime of continual learning and growth.

(4) Continually incorporate the societal and interdisciplinary implications of alternatives in his or her professional decisions.

(5) Enter graduate study, if desired, either in industrial and systems engineering or in related fields.

Bachelor of Science in Industrial and Systems Engineering

The minimum requirement for the degree is 129 units. A GPA of C (2.0) or higher is required in all upper division courses in the Department of Industrial and Systems Engineering, including any approved substitutes for these courses taken at USC. See the common requirements for undergraduate degrees, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
ISE 105aL	Introduction to Industrial and Systems Engineering	2
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		14

FIRST YEAR, SECOND SEMESTER		UNITS
ISE 105bL	Introduction to Industrial and Systems Engineering	1
CSCI 101L	Fundamentals of Computer Programming	3
MASC 110L CHEM 105aL CHEM 115aL	Materials Science, or General Chemistry, or Advanced General Chemistry	4
MATH 126	Calculus II	4
General education		4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
ECON 203	Principles of Microeconomics	4
ISE 220	Probability Concepts in Engineering	3
ISE 232L	Manufacturing Processes	3
MATH 226	Calculus III	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 205	Statics	2
ISE 225	Engineering Statistics	3
MATH 225	Linear Algebra and Linear Differential Equations	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
ISE 331	Introduction to Operations Research II	3
ISE 382	Introduction to Computer Systems, or	
CSCI 485	File and Database Management	3
General education		4
WRIT 340	Advanced Writing	3
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
ISE 410	Production II: Planning and Scheduling	3
ISE 426	Statistical Quality Control	3
ISE 435	Discrete Systems Simulation	3
ACCT 410x	Accounting for Non-Business Majors	4
Elective	departmentally approved technical elective	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
ISE 440	Work, Technology, and Organization	3
ISE 495x	Senior Design Project	4
Elective	departmentally approved technical elective	3
Elective	departmentally approved technical elective	3
		13

*Taken concurrently.

**Satisfies general education Category III.

Total units required for the program: 129.

Bachelor of Science in Industrial and Systems Engineering (Manufacturing Engineering)

If a student chooses six courses (9 to 18 units) from a prescribed program, he or she may graduate with the special designation Area of Emphasis in Manufacturing Engineering on the transcript. Details are given under Manufacturing Engineering on page 524.

General education		4
		17

THIRD YEAR, FIRST SEMESTER		UNITS
EE 326Lx	Essentials of Electrical Engineering	4
ISE 330	Introduction to Operations Research I	3
ISE 370L	Human Factors in Work Design	4
ISE 460	Engineering Economy	3
General education		4
		18

THIRD YEAR, SECOND SEMESTER		UNITS
ISE 310L	Production I: Facilities and Logistics	4

Minor in Engineering Management

This minor is designed to provide students who have a sound foundation in mathematics and the sciences with tools and skills for managerial analysis and problem solving.

Science and technology are driving significant portions of American and global economies. Individuals, companies and governments are demanding products, services and systems, which grow more complicated every day. Suppliers are forced by competition to provide goods and services efficiently and economically.

Scientists and engineers are trained in scientific and technical subjects which form an excellent base for building complex, technical products, services and systems. But more and more, scientists and engineers are managing the financial, material and human resources required to turn abstract ideas into physical and virtual reality, often without any formal management training. This minor provides that training, a complement to any science or technology degree.

Application Procedures

Applicants must be upper division students in good standing and complete the Change/Addition of Major, Minor or Degree Objective form. The minor is not open to industrial and systems engineering majors.

PREREQUISITES		UNITS
ISE 220	Probability Concepts in Engineering (or equivalent)	3
ISE 225	Engineering Statistics I (or equivalent)	3
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Linear Differential Equations (or equivalent)	4
MATH 226	Calculus III	4

REQUIRED COURSES		UNITS
ISE 330	Introduction to Operations Research I	3
ISE 370L	Human Factors in Work Design	4

ISE 440	Work, Technology, and Organization	3
ISE 460	Engineering Economy	3
ISE 485	Modern Manufacturing Systems, or	
BUAD 301	Technical Entrepreneurship	3

Master of Science in Industrial and Systems Engineering
The Master of Science in Industrial and Systems Engineering is awarded in strict conformity with the general requirements of the USC School of Engineering. This program enhances the technical capabilities of the industrial engineer. The degree requires 30 units.

REQUIRED COURSES		UNITS
ISE 514	Advanced Production Planning and Scheduling	3
ISE 515	Engineering Project Management	3
ISE 561	Advanced Engineering Economy	3
ISE 564	Performance Analysis	3
ISE 580	Advanced Concepts in Computer Simulation	3
ISE electives		9
Departmentally approved electives		6
Total units:		30

Students possessing a bachelor's degree in the physical sciences, engineering or a related field such as natural science, mathematics, or economics may work for the Master of Science in Industrial and Systems Engineering upon completion of prerequisites.

In certain cases some of the deficiencies may be waived if the applicant passes qualifying examinations, which may be either oral or written.

Additional information about the requirements for each option is available from the department.

Master of Science in Systems Architecture and Engineering
See the listing under Systems Architecture and Engineering, page 538.

Dual Degree Program (M.S./M.B.A.)
The USC Marshall School of Business in conjunction with the Department of Industrial and Systems Engineering offers a program leading to the degree of Master of Business Administration/Master of Science in Industrial and Systems Engineering.

This alternative requires 66 units for graduates of industrial and systems engineering undergraduate curricula and leads to both a Master of Science in Industrial and Systems Engineering and the Master of Business Administration. The dual degree provides an education of great depth.

The total number of units required for the M.B.A. program is 48.

Required GSBA courses include: all courses required in an M.B.A. core program — although GSBA 524 Applied Managerial Statistics and GSBA 534 Operations Management may be substituted by electives in the Marshall School of Business on the basis of successful completion of ISE 220, ISE 225 and CS 455x with grades of B or better and graduate business electives sufficient to bring the total units completed in the Marshall School of Business to at least 48.

School of Engineering

REQUIRED COURSES		(MINIMUM 18 UNITS)
ISE 514	Advanced Production Planning and Scheduling	3
ISE 515	Engineering Project Management	3
ISE 561	Advanced Engineering Economy	3
ISE 564	Performance Analysis	3
ISE 580	Advanced Concepts in Computer Simulation	3
Elective	Chosen with advisor approval	3
		18

Engineer in Industrial and Systems Engineering
Requirements for the Engineer in Industrial and Systems Engineering are the same as set forth in the general requirements.

Doctor of Philosophy in Industrial and Systems Engineering
The degree Doctor of Philosophy in industrial and systems engineering is also offered. See general requirements for graduate degrees.

Engineering Management Program
Ethel Percy Andrus
Gerontology Center 240
(213) 740-7549

This program is designed primarily, but not exclusively, for graduate engineers whose career objectives lead to increasing technical management responsibilities. Students interested in the engineering management objectives may also want to consider the M.S., Industrial and Systems Engineering/M.B.A. dual degree program.

Master of Science in Engineering Management

A total of 30 units is required for the degree. A minimum of 18 units must be taken in the Industrial and Systems Engineering Department. Eighteen units must be at the 500 level or above.

Applicants to the program are expected to have a degree in either engineering or the sciences with undergraduate course work in microeconomics and probability. Admitted students who do not meet the course work requirements will be assigned courses to complete the deficiencies.

REQUIRED COURSES		UNITS
GSBA 518	Accounting Control Systems	3
GSBA 543	Managerial Perspectives	3
IOM 533	Information Systems Analysis	3
ISE 460	Engineering Economy	3
ISE 515	Engineering Project Management	3
ISE 530	Introduction to Operations Research	3
ISE 545	Technology Development and Implementation	3
ISE 564	Performance Analysis	3
Electives		6
		30

Master of Science in Operations Research Engineering

Ethel Percy Andrus
Gerontology Center 240
(213) 740-4891

Program Coordinator: Maged Dessouky, Ph.D.

The Master of Science in Operations Research Engineering is conferred upon candidates who hold bachelor's degrees in engineering, mathematics, science or related fields who successfully complete an integrated program (with departmental approval in advance) of not less than 30 units. The program must include not less than 21 units of industrial and systems engineering courses related to operations research and 9 units of approved electives. Students will be required to make up deficiencies in mathematics and statistics. Additional courses or examinations may be required at the discretion of the department before full admission to the program. The General Test of the Graduate Record Examinations (GRE) is required. Additional information is available from the department.

REQUIRED COURSES		UNITS
ISE 520	Optimization: Theory and Algorithms	3
ISE 532	Network Flows	3
ISE 536	Linear Programming and Extensions	3
ISE 538	Elements of Stochastic Processes	3
ISE 580	Advanced Concepts in Computer Simulation	

Select at least two of the following four courses:

ISE 513	Inventory Control (3)	
ISE 514	Advanced Production Planning and Scheduling (3)	
ISE 516	Facilities Location and Layout (3)	
ISE 527	Advanced Quality Control (3)	6
400- or 500-level computer science course, approved by faculty advisor		3
Two electives, approved by faculty advisor		6
		30

Courses of Instruction

INDUSTRIAL AND SYSTEMS ENGINEERING (ISE)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

105abL Introduction to Industrial and Systems Engineering (2-1, a: Fa; b: Sp) Gateway to the bachelor of science in industrial and systems engineering. A combination of plant tours, laboratory experiences, and lecture are used to introduce the philosophy, subject matter, aims, goals, and techniques of industrial and systems engineering.

107 Technical Communications (3, FaSp) Written, oral, and visual communication of industrial/systems engineering. Formats and strategies for written documents; instruction and practice in oral presentations; ways to represent data visually. *Prerequisite:* WRIT 140.

220 Probability Concepts in Engineering (3, FaSp) Techniques for handling uncertainties in engineering design: discrete and continuous random variables; expectations, probability distributions and transformations of random variables; limit theorems; approximations and applications. *Corequisite:* MATH 226.

225 Engineering Statistics I (3, FaSp) Sampling distributions; parameter estimation, hypothesis testing; analysis of variance; regression; nonparametric statistics. *Prerequisite:* ISE 220.

232L Manufacturing Processes (3, Fa) Basic manufacturing processes including casting, machining, forming and welding; current trends in manufacturing processes including polymer, ceramic and composite material processing, and electronic device fabrication; introduction to numerical control and computer integrated manufacturing. *Prerequisite:* MASC 110*L* or CHEM 105*aL* or CHEM 115*aL*.

310L Production I: Facilities and Logistics (4, Sp) Facilities layout and design; material handling and transportation; site selection and sourcing; supply chain management. *Prerequisite:* ISE 330, ISE 460; *corequisite:* ISE 331.

330 Introduction to Operations Research I (3, Fa) Introduction to linear programming; transportation and assignment problems; dynamic programming; deterministic inventory models and Markov chains. *Prerequisite:* MATH 225.

331 Introduction to Operations Research II (3, Sp) Stochastic processes; Markov chains; queueing theory and queueing decision models; probabilistic inventory models; PERT-CPM; simulation and output analysis. *Prerequisite:* ISE 220, ISE 330.

370L Human Factors in Work Design (4, Fa) Physiological systems and psychological characteristics; ergonomics; anthropometry; effects of the physical environment on humans; occupational safety and health; work methods. *Prerequisite:* ISE 225.

382 Introduction to Computer Systems (3, Sp) Fundamental concepts of modern computer systems; design of industrial information systems including hardware selection, software design, human/machine interface, and data processing economics. *Prerequisite:* CSCI 101*L*.

390 Special Problems (1-4) Supervised, individual studies. No more than one registration permitted. Enrollment by petition only.

410 Production II: Planning and Scheduling (3, Fa) Production planning, forecasting, scheduling, and inventory; computer integrated decision systems in analysis and control of production systems. *Prerequisite:* ISE 330, ISE 310*L*.

415 Industrial Automation (3) Traditional (automobile) and modern (computer based) concepts in Industrial Automation. Computer control concepts (sensors, actuators), robotics, flexible manufacturing systems. *Prerequisite:* senior level status.

426 Statistical Quality Control (3, Fa) Quantitative aspects of statistical quality control (process control, acceptance sampling by attribute and by variable, rectifying inspection), quality assurance and the management of QC/QA functions. *Prerequisite:* ISE 225.

435 Discrete Systems Simulation (3, FaSp) Model design to simulate discrete event systems with basic input and output analysis using high order languages, applied to industrial systems analysis and design problems. *Prerequisite:* ISE 220, CSCI 101*L*; *corequisite:* ISE 225.

440 Work, Technology, and Organization (3, Sp) Impact of technology on work and organizational design; effects of automation; design of improvement programs; information infrastructures; teams; individual behavioral outcomes. *Prerequisite:* senior level standing in Engineering.

457 Modeling of Manufacturing Systems (3, Sp) Methodologies and tools for design, operations planning, and control, and performance analysis of production systems. Roles of optimization, analytical evaluation, and simulation are discussed and demonstrated. *Prerequisite:* ISE 220; CSCI 101*L*; MATH 225, MATH 226.

460 Engineering Economy (3, FaSp) Utilizing principles of economic analysis for choice of engineering alternatives and engineering systems. Pre-tax and after-tax economy studies. (Duplicates credit in former ISE 360.) *Prerequisite:* upper division standing.

485 Modern Manufacturing Systems (3, Fa) Roles of manufacturing enterprises in society, economy, and environment; their resources, related challenges, and problems; tools and technologies for their design, operation, and analysis. (Duplicates credit in former ISE 250.) *Prerequisite:* junior standing.

490x Directed Research (2-8, max 8, FaSp) Individual research and readings. Not available for graduate credit. *Prerequisite:* departmental approval.

495x Senior Design Project (4, Sp) Group work on an industrial engineering design problem in an organization. Not available for graduate credit. *Prerequisite:* senior standing in ISE.

498x Foundations of Industrial and Systems Engineering (4, Fa) Review of industrial engineering fundamentals, covering human factors, work analysis, facility layout, and production planning and control. Not available for credit to industrial and systems engineering majors, graduate or undergraduate, or for graduate credit to engineering management, manufacturing engineering, and operations research engineering majors.

499 Special Topics (2-4, max 8) Course content to be selected each semester from recent developments in industrial and systems engineering and related fields.

511L Computer Aided Manufacturing (3, Sp) Modern industrial automation, numerical control concepts, programmable controllers, robotics, computer-process interfacing, automated process and quality control, flexible manufacturing systems, introduction to computer-integrated manufacturing systems.

513 Inventory Systems (3, Sp) Deterministic and stochastic demand systems with static/dynamic models. Practice in inventory management, computerized procedures, materials requirements planning, just-in-time production, Kanban systems.

514 Advanced Production Planning and Scheduling (3, Fa) Advanced concepts in production planning and scheduling including resource allocation, lot sizing, flow shop and job shop scheduling, workforce scheduling and assembly line balancing. *Recommended preparation:* prior knowledge of operations research and probability theory.

515 Engineering Project Management (3, FaSp) Applying industrial and systems engineering skills to problems drawn from industry, while working in teams of 3-4 students. Teach project management skills and provide direct experience in managing and executing a group project.

516 Facilities Location and Layout (3, Sp) Problems of location and layout for single or multiple facilities; applications in plant, warehouse, emergency service contexts; quantitative models and solution techniques for these problems.

517 The Modern Manufacturing Enterprise System (3, Fa) Study of various aspects of integrated manufacturing enterprises including management, design and production functions, interfaces and related resources and information systems. *Recommended preparation:* manufacturing processes, probability, statistics, computer programming.

520 Optimization: Theory and Algorithms (3, Sp) Conditions for optimality. Nonlinear programming algorithms for constrained and unconstrained problems. Special problems such as quadratic, separable, fractional, geometric programming. *Prerequisite:* MATH 225 or EE 441, or departmental approval.

525 Intermediate Engineering Statistics II (3, Fa) Intermediate statistical methods in design of experiments; analysis of variance and hypothesis testing.

527 Advanced Quality Control (3, Fa) Advanced topics in the economic design and use of acceptance sampling and control charting; applications of modern statistical theory in the quality assurance.

528 Advanced Statistical Aspects of Engineering Reliability (3, Sp) Advanced statistical methods applied to reliability engineering. Experimental design analysis and interpretation of multifactor reliability problems.

530 Introduction to Operations Research (3, SpSm) Linear programming, integer programming, transportation and assignment problems, networks, dynamic programming, Markovian models, and queueing. *Prerequisite:* MATH 225, ISE 220.

532 Network Flows (3, Sp) Tree, path, flow problems, formulation and solution techniques. Methods for minimal cost flows. Applications. *Prerequisite:* ISE 330 or ISE 536 or departmental approval.

535 Continuous Systems Simulation (3, Sp) Analysis of continuous systems via simulation; concepts of combined discrete and continuous system modeling; emphasis on simulation of large-scale industrial and systems engineering problems and related physical systems.

536 Linear Programming and Extensions (3, Sp) Linear programming models for resource allocation; simplex and revised simplex methods; duality; sensitivity; transportation problems; selected extensions to large scale, multiobjective, and special structured models. *Prerequisite:* MATH 225 or EE 441 or departmental approval.

538 Elements of Stochastic Processes (3, Sp) Random variables, stochastic processes, birth-and-death processes, continuous and discrete time Markov chains with finite and infinite number of states, renewal phenomena, queueing systems.

540 Advanced Topics in Work Measurement and Methods Analysis (3, Fa) Derivation and application of standards and the analysis and design of human work tasks. Review and discussion of literature.

541 Systems Engineering Methodology (3, Fa) Integration of engineering problem solving methodologies based on systems concepts. Application to complex, large scale technical systems and problems faced by engineering managers. Case studies. *Prerequisite:* ISE 515.

544 Management of Engineering Teams (3, Sp) Design and management of engineering teams. Group decision-making, motivation, leadership, infrastructural requirements, performance measurement, team diversity, conflict, and integration.

545 Technology Development and Implementation (3, Sp) Principles and practices of technology development and implementation, with application to products and systems in manufacturing and services.

549ab Systems Architecting (3-3, Fa) (Enroll in AE 549*ab*)

550 The Political Process in Systems Architecture Design (3, Fa) Exploration and analysis of the intimate interaction between the political process and the engineering design process in high-tech, high-cost programs. "Designing the politics in." *Prerequisite:* undergraduate degree in engineering or related field plus two years of work experience.

561 Advanced Engineering Economy (3, Sp) Advanced topics. Economic evaluations of engineering systems for both government and private industry; quantitative techniques for evaluating non-monetary consequences; formal treatment of risk and uncertainty. *Prerequisite:* ISE 460.

562 Value and Decision Theory (3, Fa) Decision making under risk conditions; utility theory; sufficient statistics; conjugate prior distributions; terminal and pre-posterior analysis; Bayesian statistics versus classical statistics.

564 Performance Analysis (3, Sp) Measurement systems for performance analysis. Determination of performance metrics, analytical models, case studies. Cross-industry comparisons, measures for manufacturing and service systems, information and knowledge workers.

570 Human Factors in Engineering (3, Fa) Psychological and physiological characteristics of humans; how they limit engineering design of machines and human-machine systems.

573 Work Physiology (3) Survey of metabolic processes in the performance of physical work, study of individual and environmental factors affecting these processes.

574 Cognitive Engineering (3, Sp) Design of complex automated systems based on current models of human cognition, skill acquisition, and skill use. Skill levels, user learning, functional allocation considered.

580 Advanced Concepts in Computer Simulation (3, Sp) Coverage of various stages of simulation processes using a project and case study oriented approach; an introduction to available simulation tools and modern simulation concepts. *Prerequisite:* ISE 220, ISE 325, ISE 435.

582 Information Technology for Industrial Engineering (3, Fa) Basic functional understanding of object oriented modeling; database systems; enterprise information; and distributed systems. *Prerequisite:* ISE 382.

585 Strategic Management of Technology (3, Sp) Management skills and tools for technology intensive enterprises. Life cycle analysis of technology from planning through exploitation, obsolescence and renewal.

590 Directed Research (1-12) Research leading to the master's degree; maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

594abz Master's Thesis (2-2-0) Credit on acceptance of thesis. Graded IP/CR/NC.

599 Special Topics (2-4, max 9, Fa) Course content will be selected each semester to reflect current trends and developments in the field of industrial and systems engineering.

650abcd Seminar in Industrial Engineering (1/2, 1/2, 1/2, 1/2, FaSp) Reports on current departmental research; review of papers, proposals, and special projects; guest speakers. Required of all students enrolled in Ph.D. program.

690 Directed Research (1-4, max 8, FaSpSm) Laboratory study of specific problems by candidates for the degree Engineer in Industrial and Systems Engineering. Graded CR/NC.

790 Research (1-12, FaSpSm) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Information Technology Program

Olin Hall 412
(213) 740-4542
Email: itp@usc.edu

Director: Kelly Goulis, M.S.

Instructors: Nitin Kale, M.S.; Rebecca Mundy, M.S.; George O. Petrovay, M.S.; Mary Pruitt, M.S.; Richard Vawter, M.S.; Richard Wainess, M.S.; Barbara Yin, Ph.D.

All ITP courses are open to non-engineering majors. The "x" designation indicates that engineering students require prior departmental approval to count 100-level and above ITP courses for major credit.

Courses of Instruction

INFORMATION TECHNOLOGY PROGRAM (ITP)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

010x Supporting Microsoft Windows 95 (2, FaSpSm) Installing, configuring, customizing, optimizing, administrating, and troubleshooting Windows 95. Networking issues such as integrating and messaging. *Prerequisite:* extensive experience with Windows version 3.x. Not available for degree credit. Graded CR/NC.

011x Supporting Microsoft Windows NT (2, FaSpSm) Configuring, customizing, optimizing, integrating, and troubleshooting Microsoft Windows NT operating system. Interoperating with IPX and TCP/IP. Not available for degree credit. Graded CR/NC. *Prerequisite:* extensive knowledge of Windows and network concepts.

012x Supporting Microsoft Windows NT Server (2, FaSpSm) Installing, configuring, and supporting the Microsoft Windows NT Server operating system in local and wide area network (WAN) environments. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 011*x*.

013x Windows Architecture for Developers (2, FaSpSm) Architecture and services of the Microsoft Windows operating systems. Development of solutions for current Windows platforms. Graded CR/NC. Not available for degree credit.

014x Supporting Microsoft Internet Information Server (1) Overview of installing, configuring, and supporting Internet Information Server. Support for FTP, Gopher, WWW, and WAIS. Implementing and planning a complete internet site. Graded CR/NC.

015x System Administration for Microsoft SQL Server (2) Installing, configuring, administering, and troubleshooting Microsoft SQL Server. Hands-on laboratories managing user accounts, login security, database permissions, and backing up and restoring a database. Graded CR/NC.

016x Networking Essentials (1, FaSpSm) Basic concepts of local area networks, WANs, data communications, and connectivity. Network protocols, media types, network architecture, topologies, cabling, and transmission. Not available for degree credit. Graded CR/NC.

017x Internetworking Microsoft TCP/IP (2, FaSpSm) Setting up, configuring, using, and supporting Transmission Control Protocol/Internet Protocol (TCP/IP) in the Windows environment. (Duplicates credit in former ITP 076*x*.) Not available for degree credit. *Prerequisite:* ITP 011*x*.

018x Core Technologies of Microsoft Exchange Server (2, FaSpSm) Administration of Microsoft Exchange in a single-site or multiple-site environment; integration with Novell, Outlook, and Lotus email. Graded CR/NC. Not available for degree credit. *Prerequisite:* ITP 011*x*.

022x Word Processing Using Microsoft Word (1) Overview of word processing and basic microcomputer operations using Microsoft Word. Basic document creation, editing, formatting, and printing. Spell-checking, document merging, searching, and replacing. Not available for degree credit. Graded CR/NC.

031x Introduction to Microsoft Excel (1) Spreadsheet applications on microcomputers using Microsoft Excel; fundamentals of problem solving and data analysis using a wide variety of spreadsheet features. Not available for degree credit. Graded CR/NC.

042x Introduction to Microsoft Windows (1) Practical knowledge and insight into Windows and software using character and graphical based applications and multitasking. Installation, configuration, and optimization. Not available for degree credit. Graded CR/NC.

043x The Internet (2, FaSp) Overview of the Internet, effective searching techniques, connection protocols; use of email, newsgroup, real-time chat, World Wide Web. Internet security and server issues. Not available for degree credit. Graded CR/NC.

046x Introduction to Web Publishing (1, FaSp) Overview of HTML and CGI Script languages to publish static and interactive homepages on the World Wide Web using browsers and appropriate tools. Not available for degree credit. Graded CR/NC.

050x Microsoft Power Point (1, FaSpSm) Overview of how to create professional and colorful screen presentations, overhead transparencies, outlines and 35 mm slides using a presentation graphics program. Not available for degree credit. Graded CR/NC.

065x Microsoft Access (1, FaSpSm) Microsoft Access will allow students to learn how to plan, define, create, and modify a database in the Windows environment. Not available for degree credit. Graded CR/NC.

068x Introduction to MATLAB (2, FaSpSm) Fundamentals of MATLAB: a high-performance numeric computation and visualization environment. Overview of linear algebra and matrix manipulation; using 2-D and 3-D plotting routines; programming in MATLAB; basic numerical analysis. Not available for degree credit. Graded CR/NC. *Recommended preparation:* MATH 118*x* or MATH 125.

072x Networking Technologies (1, FaSpSm) Basic concepts of data communications, networking, and connectivity. Data translation; data transmission; network structures; low-layer, IEEE 802, and super-layer communication protocols. Not available for degree credit. Graded CR/NC.

073x NetWare Service and Support (2, FaSpSm) Installing, maintaining, troubleshooting NetWare networks. Hands-on laboratories on network adapter configurations, network cabling, disk expansion, troubleshooting techniques, and common network problems. Not available for degree credit. Graded CR/NC.

077x NetWare NFS (1, FaSpSm) Installation of configuration of NetWare NFS software. The mounting of remote file systems and directories from UNIX clients. Sharing of NetWare printers with UNIX clients. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 074*x*, ITP 076*x*.

078x NetWare 3.1x Installation and Configuration Workshop (1, FaSpSm) Overview of installing and configuring the NetWare 3.1x network operating system, upgrading from NetWare 3.11 to 3.1x, and installing DOS client software. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 075*x*.

079x Printing with NetWare (1, FaSpSm) Managing and configuring Novell NetWare printing. Hands-on experience configuring workstations, customizing print jobs, setting up print servers and queues, and establishing remote printing. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 074*x* and ITP 084*x*.

084x NetWare Administration (2, FaSpSm) Basic management of the Novell network operating system. Also covers advanced administration topics. Not available for degree credit. Graded CR/NC. Duplicates credit in former ITP 085*x*.

090x Introduction to Adobe Photoshop (2, FaSpSm) Basic concepts of colors; color calibration tools; scanning, importing and exporting images; painting, editing, fill, and type tools; using layers, masks, filters, and color correction. Not available for degree credit. Graded CR/NC.

091x Intermediate Adobe Photoshop (2, FaSpSm) Advanced use of layers, layer masks, channels, and filters to create special effects. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 090*x*.

093x Introduction to Adobe Illustrator (2, FaSpSm) Basic concepts of drawing paths, selection tools, painting, type, transformation tools, filters and graphs. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 042*x*.

095x Introduction to Adobe Premiere (2, FaSpSm) Basic concepts of importing images, video and sound, tracks, editing, previewing, transitions, filters, motion settings, superimposing, titles, special effects and exporting. Not available for degree credit. Graded CR/NC. *Prerequisite:* ITP 042*x*.

100x Information Technology for Business (2, FaSp) Introduction to current operating systems and architecture; survey of the latest uses of applications software in business; networking concepts, programming languages and fundamentals of programming.

101x Introduction to Information Technology (4, FaSpSm) Introduction to computer hardware, operating systems, networks, programming. Survey of application software in business and industry. Computer issues in the work place and society.

102x Introduction to BASIC Programming (2, FaSpSm) Fundamental concepts of programming using minimal BASIC. A structural approach to problem solving emphasizing business applications. *Prerequisite:* high school algebra.

103x Introduction to FORTRAN Programming (2) Algorithmic approach to problem solving; fundamentals of Structured FORTRAN 77; numerical solutions with DO loops and IF statements; formatted I/O; one-dimensional arrays; functions and subroutines. *Prerequisite:* high school algebra.

104x Internet Technologies (2, FaSp) Survey of Internet protocols, networking, services, browsers, search engines. Basic Web authoring using HTML and JavaScript. Web page style and design, multimedia, performance issues and ethics. *Prerequisite:* ITP 100 or ITP 101 or ITP 105.

105x Introduction to Computer Technologies and Applications (2, FaSp) The course offers a primer in computer technologies and applications essential to academic and career success. Not available for major credit to engineering majors.

106 Information Literacy and Technology Issues (2, FaSp) A basic course in research and electronic information retrieval, including evaluative procedures and ethical issues.

109x Introduction to Java Programming (2, Sp) Fundamental concepts of object oriented programming in a multi-threaded environment. Creation of interactive WWW applets, featuring animations, sounds and images. *Prerequisite:* ITP 110*x*.

110x Introduction to C Programming (2) Fundamentals of C; a survey of C compilers; the role of C in developing Unix and other operating systems. *Prerequisite:* knowledge of a higher-level language.

150x Introduction to Visual BASIC (2, FaSp) This course provides students with no previous programming experience with the basics for and creating their own interactive windows applications using visual programming techniques. *Prerequisite:* high school algebra.

165x Introduction to C++ Programming (2, Fa) Fundamentals of C++ syntax and semantics, including function prototypes, overloading, memory management, abstract data types, object creation, pointers to class members, and I/O streams. *Prerequisite:* any high-level programming language.

201x Microcomputer Applications (2, FaSp) Advanced applications for microcomputers including database management, statistical data analyses, and statistics. *Prerequisite:* ITP 100*x* or ITP 101*x*.

203x Advanced Programming with Engineering Applications (3) Multidimensional arrays; linear systems; numerical solutions of nonlinear equations; polynomials and integrals; computer graphics and other related topics (e.g., simulations) Not available for credit to CSCI or EE majors. *Prerequisite:* ITP 103*x* or ITP 105*x* or ITP 110*x*, MATH 125.

210x Multimedia Applications for Windows (2, Fa) Focuses on creating powerful presentations with affordable multimedia hardware and software; integrates sound, video and animation into windowing environment. *Prerequisite:* ITP 101*x* or ITP 201*x*.

211x Multimedia Authoring (2, FaSpSm) Overview of multimedia authoring tools; integrating audio/graphics/video to create interactive multimedia using Multimedia Authoring Tools. Introduction to Object Oriented Lingo (OOL); working with Shockwave to create interactive web pages. *Recommended preparation:* ITP 210, any high level programming language.

215x 3D Modeling, Animation, Compositing and Special Effects (2, FaSpSm) Overview of developing a 3D animation: from modeling to rendering. Basics of surfacing, lighting, animation and modeling techniques. Advanced topics: compositing, particle systems, and character animation. *Prerequisite:* knowledge of any 2D paint, drawing or CAD program.

220x Video Editing and Effects for Multimedia, the Web, and Broadcast (2, FaSpSm) Techniques for digital, non-linear video editing and compositing. Special video effects, rendering and compression for multimedia, the Web, and Broadcast. *Recommended preparation:* general PC-based computer proficiency.

225x The UNIX System (2) UNIX system concepts; the Shell command language; utilities, editors, file structure, and text formatters. C Shell, Bourne Shell, and the awk programming language. *Prerequisite:* ITP 101*x*.

250x Building Client/Server Applications (2) Fundamentals of Client/Server architecture and development tools; hands-on laboratories using Visual Basic, ODBC, and SQL Server Database Engines; overview of network operating systems.

265x Advanced C++ and Java Application (2, SpSm) Advanced application programming techniques using C++ and Java in an integrated visual development environment with foundation classes, database connectivity and client/server architecture. *Prerequisite:* ITP 109 or ITP 165 or CSCI 101*L*.

315x Applications for 3D Special Effects and Character Animation (2) This advanced 3D animation course explores applications for various special effects processes, focusing on the use of particle systems, texture mapping, character and facial animation, and live action compositing. *Prerequisite:* ITP 215*x*.

320x Enterprise Wide Information Systems (2, FaSpSm) The role that Information Systems play in an organization and the challenging task of implementing and managing the IS function are both examined in detail. *Prerequisite:* ITP 101*x*.

321x Programming Enterprise Wide Information Systems (2, FaSpSm) Programming enterprise applications using ABAP/4. Topics include: ABAP/4 Development Workbench, Data Dictionary, Subroutines and Functions, database tables, data objects, and designing reports. *Prerequisite:* ITP 320.

411x Interactive Multimedia Production (3, FaSpSm) Interactive multimedia title development cycle. Programming a time-based authoring tool; design, develop, and deliver a multimedia title on the Web and state-of-the-art storage media. *Prerequisite:* proficiency in object-oriented programming.

413x Interactive Web Development (4, FaSpSm) Covers most technical aspects of producing interactive online Web pages on the World Wide Web, through the use of development tools for publishing. *Prerequisite:* JOUR 412 or working knowledge of HTML.

454x Enterprise Resource Planning, Design, and Implementation (3, FaSp) An in-depth look at the process and requirements necessary to implement an Enterprise Resource Planning System (ERP). Students will set up a server system, implement an ERP system, then transfer and configure a database for a case company. *Prerequisite:* ITP 320x; *corequisite:* ACCT 454.

499x Special Topics (2-4, max 8) Recent developments in computers and data processing.

555 Functionality of Enterprise Resource Planning Systems (1, FaSp) The functionality of Enterprise Resource Planning Systems (ERPs); the methods of implementation and the integration of information throughout an organization are discussed and analyzed. *Concurrent enrollment:* ACCT 555; *recommended preparation:* ACCT 547 or GSBA 530.

Manufacturing Engineering

Ethel Percy Andrus
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Email: efelina@usc.edu

Program Director: B. Khoshnevis, Ph.D.

Undergraduate Area of Emphasis in Manufacturing Engineering
This program has been created in response to the national need to train more engineers who are knowledgeable in contemporary manufacturing. An area of emphasis in manufacturing engineering is available to B.S. students in the Departments of Chemical Engineering, Computer Science, Electrical Engineering, Industrial and Systems Engineering and Mechanical Engineering. This area of emphasis (so designated on the student's transcript) requires the completion of six courses (9 to 18 units) beyond the normal department requirements. The program provides for a common core of courses and a wide selection of electives, depending on the student's interest. It is likely that students selecting this emphasis as part of their program will require more than eight semesters to complete the requirements for the B.S. degree.

REQUIRED COURSES		UNITS
ISE 485	Modern Manufacturing Systems	3
ISE 232L	Manufacturing Processes, or	
ME 232	Manufacturing Processes	3
One course from the following list:		
CSCI 446	Robotics and Sensing for Automated Assembly	3
CSCI 482	Introduction to Geometric Modeling	3
EE 438L	Processing for Microelectronics	3
EE 479L	Introduction to Integrated Circuit Design	4
ISE 457	Modeling of Manufacturing Systems	3

Three courses from the following lists. A maximum of two of these courses may also be used to satisfy department requirements:

CHEMICAL ENGINEERING		UNITS
CHE 460L	Chemical Process Dynamics and Control	4
CHE 472	Polymer Science and Engineering	3
CHE 474L	Polymer Science and Engineering Laboratory	3
CHE 476	Chemical Engineering Materials	4
CHE 477	Computer Assisted Polymer Engineering I: Thermoplastic Polymers	3
CHE 478	Plastic Materials	3
CHE 480	Chemical Process and Plant Design	3
CHE 485	Computer Aided Chemical Process Design	3

COMPUTER SCIENCE		UNITS
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477L	Design and Construction of Large Software Systems	4
CSCI 480	Computer Graphics	3
CSCI 485	File and Database Management	3
EE 450	Introduction to Computer Networks	3
EE 454L	Introduction to Systems Design Using Microprocessors	4

ELECTRICAL ENGINEERING		UNITS
EE 443	Introduction to Power Systems	3
EE 454L	Introduction to Systems Design Using Microprocessors	4
EE 459L	Senior Design Project	3
EE 478L	Digital and Electronic Circuit Design	4
EE 482	Linear Control Systems	3

INDUSTRIAL AND SYSTEMS ENGINEERING		UNITS
ISE 410	Production Planning and Control	3
ISE 411L	Facilities Analysis and Design	3
ISE 415	Industrial Automation	3
ISE 426	Statistical Quality Control	3
ISE 435	Discrete Systems Simulation	3
ISE 440	Social Organization and Technology	3
ISE 477L	Work Analysis and Design	3
ISE 495x	Senior Design Project	3

MECHANICAL ENGINEERING		UNITS
ME 231	Properties and Selection of Materials	3
ME 232	Manufacturing Processes	3
ME 407	Computer Graphics for Mechanical Engineers	3
ME 408	Computer-Aided Design of Mechanical Systems	3
ME 409	Senior Design Project	4
ME 452	Intermediate Kinematics	3

Master of Science in Manufacturing Engineering

Manufacturing engineering at USC is a multidisciplinary program that confers the degree of Master of Science and is designed to produce graduates capable of responding to the needs of modern, up-to-date manufacturing. These graduates should be able to design, install and operate complex manufacturing systems made up of people, materials, automated machines and information systems. The Departments of Computer Science, Electrical Engineering, Industrial and Systems Engineering, Materials Science, Mechanical Engineering, and Entrepreneurship participate in the Manufacturing Engineering Program.

Course work in the program will train students in traditional manufacturing engineering topics, such as materials selection and process design. Additional courses will include the more modern, system-level concepts of integrated product and process design, applications of modern information technology to design and manufacturing, hands-on laboratories using advanced manufacturing equipment and commercial software, and entrepreneurship.

Curriculum

A total of 30 units is required beyond the B.S. degree. A minimum of 21 units must be at the 500 level or above. A maximum of 6 units of electives may be taken from non-engineering departments. At least three courses must be taken in the student's selected area of specialization.

REQUIRED COURSES		UNITS
ISE 511L	Computer Aided Manufacturing	3
ISE 517	The Modern Manufacturing Enterprise System	3
ISE 525	Intermediate Engineering Statistics II, or	
ME 525	Engineering Analysis	3
CSCI 585	Database Systems, or	
ENGR 450	Introduction to Computer Networks	3
Approved electives*		18
		30

*A list of approved electives in specialization areas is available from the department. Departmental approval is required for courses not listed.

Materials Science

Vivian Hall of Engineering 602
(213) 740-4339
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Email: masc@usc.edu

Chair: Florian Mansfeld, Ph.D.

Faculty

M.C. Gill Chair in Composite Materials: Steven R. Nutt, Ph.D. (*Mechanical Engineering*)

Kenneth T. Norris Professorship in Engineering: Anupam Madhukar, Ph.D. (*Physics*)

Professors: Larry Dalton, Ph.D. (*Chemistry*); P. Daniel Dapkus, Ph.D. (*Electrical Engineering*); Bruce Koel, Ph.D. (*Chemistry*); Terence G. Langdon, Ph.D., D.Sc. (*Mechanical Engineering and Earth Sciences*); Anupam Madhukar, Ph.D. (*Physics*); Florian Mansfeld, Ph.D. (*Chemical Engineering*); Steven R. Nutt, Ph.D. (*Mechanical Engineering*); Ronald Salovey, Ph.D. (*Chemical Engineering*); Charles G. Sammis, Ph.D. (*Earth Sciences*)*; Mark E. Thompson, Ph.D. (*Chemistry*)

Associate Professors: Edward Goo, Ph.D.; Daniel H. Rich, Ph.D.; Armand R. Tanguay, Jr., Ph.D. (*Electrical Engineering*)

Emeritus Professors: Clarence R. Crowell, Ph.D. (*Electrical Engineering*); Murray Gershenzon, Ph.D. (*Electrical Engineering*); Ferdinand A. Kroger, Ph.D.; Kurt Lehovec, Ph.D. (*Electrical Engineering*); Jan Smit, Ph.D. (*Electrical Engineering*); William G. Spitzer, Ph.D. (*Physics and Electrical Engineering*); James M. Whelan, Ph.D. (*Electrical Engineering and Chemical Engineering*); David B. Wittry, Ph.D. (*Electrical Engineering*)

*Recipient of university-wide or school teaching award.

Minor in Materials Science

A minor in materials science is open to all undergraduate students in engineering. This minor provides students with background and skills necessary to understand and use advanced materials in different engineering applications. Students are required to complete a minimum of 16 units of course work consisting of both core requirements and elective courses. Students must include at least four upper division courses of either three or four units in the minor program.

Students must apply to the School of Engineering for the minor, and departmental approval is required. The program is outlined as follows:

REQUIRED COURSES		UNITS
CE 225	Mechanics of Deformable Bodies	3
MASC 310	Materials Behavior and Processing	3
MASC 440	Materials and the Environment	3
CHE 476	Chemical Engineering Materials, or	3
CE 334L	Mechanical Behavior of Materials	3
Advisor approved electives	(minimum)	4
		16

ELECTIVES		UNITS
BME 410	Introduction to Biomaterials	3
CE 334L	Mechanical Behavior of Materials	3
CE 428	Mechanics of Materials	3
CE 467L	Geotechnical Engineering	4
CHE 472	Polymer Science and Engineering	3
CHE 476	Chemical Engineering Materials	3
MASC 350	Design, Synthesis, and Processing of Engineering Materials	3
MASC 439	Principles of Semiconductor Processing	3

Master of Science in Materials Science

In addition to the general requirements for the Master of Science degree, add the following required courses: MASC 501, 503, 504, 505, 539 and 561. The nine remaining units for the degree may be electives chosen with departmental approval.

Engineer in Materials Science

Requirements for the Engineer in Materials Science degree are the same as set forth in the general requirements for graduate degrees.

Doctor of Philosophy in Materials Science

The Doctor of Philosophy with a major in materials science is awarded in strict conformity with the general requirements of the USC Graduate School. It includes the course requirements for the Master of Science degree. See general requirements for graduate degrees.

Master of Science in Materials Engineering

Students with an interest in the characterization, selection and processing of engineering materials, and in materials problems related to engineering design may work toward a Master of Science in Materials Engineering. This degree is awarded in conformity with the general requirements of the School of Engineering. Students may elect to work for this degree in either the Materials Science or Mechanical Engineering Departments. The specific courses that constitute an acceptable program must be approved in advance by the administering department.

Courses of Instruction

MATERIALS SCIENCE (MASC)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

110L Materials Science (4, FaSp) Chemical bonding and structure in crystalline, amorphous, and molecular solids; tendency and mechanisms for chemical change; homogeneous and heterogeneous equilibria. *Prerequisite:* high school chemistry.

310 Materials Behavior and Processing (3) Principles of mechanical behavior and processing of materials. Relationships between mechanical properties, microstructure, and processing methods. Composites and nonmetallics included.

350 Design, Synthesis and Processing of Engineering Materials (3) Structure, properties, synthesis, processing and design of metallic, ceramic, polymeric, electronic, photonic, composite, nanophase and biomaterials; nanostructures, microfabrication and smart materials. *Prerequisite:* CHEM 105*a* or MASC 110*L*, PHYS 152.

437 Fundamentals of Solid State (3) Atomic theory; wave mechanics; crystal structure; lattice vibrations; elasticity theory; free electron and tight bonding approximations. *Prerequisite:* MASC 110*L* or EE 338, PHYS 153*L*, and MATH 445.

438L Processing for Microelectronics (3) (Enroll in EE 438*L*)

439 Principles of Semiconductor Processing (3) Principles relevant to semiconductor processing are covered. Topics include bulk and epitaxial crystal growth, photolithography, evaporation, sputtering, etching, oxidation, alloying, and ion implantation. *Prerequisite:* MASC 110*L*, EE 338.

440 Materials and the Environment (3, Sp) Interactions of metals, alloys and composite materials with liquid and gaseous corrosive environments; corrosion protection by alloying and application of inhibitors and metallic or organic coatings.

471 Applied Quantum Mechanics for Engineers (3) (Enroll in EE 471)

472 Polymer Science and Engineering (3) (Enroll in CHE 472)

475 Physical Properties of Polymers (3) (Enroll in CHE 475)

476 Chemical Engineering Materials (3) (Enroll in CHE 476)

478 Plastic Materials (3) (Enroll in CHE 478)

501 Solid State (3, Sp) Atomic structure, bonding in covalent, ionic and Van der Waals crystals, Brillouin zones, lattices, diffraction, electronic states, lattice vibrations, specific heat, electrical conductivity, and magnetism. *Prerequisite:* EE 539.

502 Advanced Solid State (3, Fa) Semiconductors, dielectrics and metals, thermoelectric effects, magnetism, magnetic resonance and superconductivity. *Prerequisite:* MASC 501.

503 Thermodynamics of Materials (3, Fa) Classical thermodynamics, chemical potential, pure phases and mixtures; interphase relationships; binary and ternary solutions; free energy and activity; galvanic cell, electrochemical potential and Pourbaix diagram.

504 Diffusion and Phase Equilibria (3, Sp) Phase equilibria; phase diagrams; diffusion; planar defects; nucleation and growth; spinodal decomposition; phase transformation. *Prerequisite:* MASC 503.

505 Crystals and Anisotropy (3, Fa) Stereographic projection; Laue back reflection method; crystal orientation; line and planar crystalline defects; tensors; susceptibility; permeability and permittivity; stress and strain; piezoelectricity; elasticity.

506 Semiconductor Physics (3, Fa) (Enroll in EE 506)

507 Magnetic and Dielectric Properties of Materials (3) Definitions, properties of field quantities, electric and magnetic energy; exchange coupling; ferro-, ferri-, and antiferromagnetism; ferro-electricity; crystalline anisotropy; permeability; dielectric constants; resonance; spin waves; relaxation. *Prerequisite:* MASC 502.

508 Imperfections in Solids (3) Types of imperfections; point defects, dislocations; effects on optical, electrical, magnetic, and mechanical properties of solids; phase equilibria involving point defects; imperfection pairing; intersolubility effects. *Prerequisite:* MASC 502 and MASC 503.

509 Phase Transformations (3) Thermodynamics and kinetics of nucleation and growth, crystallographic processes in diffusional transformations, precipitation from solid solutions, eutectoid decomposition, cellular phase separation, ordering reactions, diffusionless transformations. *Prerequisite:* MASC 504.

510 Surface and Interface Phenomena (3) Behavior of solid surfaces, solid-vacuum and solid-solid interfaces and their applications. Study of electronic structure, kinetic and dynamic behavior of surface phenomena. *Prerequisite:* MASC 501, MASC 506.

511 Materials Preparation (3) Principles and techniques of materials preparation; purification, crystal growth from liquid and vapor phases, sintering. *Prerequisite:* MASC 504 or MASC 509.

512 Epitaxial Growth (3) Epitaxy, coherence, incoherence and pseudomorphism; thermodynamic approaches, Wilson-Frenkel law, kinetic equation approach, nucleation and continuous growth mechanisms, cluster dynamics, lattice mismatch and misfit dislocations. *Prerequisite:* MASC 501, MASC 503.

513 Multilayered Materials and Properties (3) Fabrication methods, structural determination via X-ray and electron diffraction, electrical behavior, optical properties via absorption, luminescence, and light scattering. *Prerequisite:* MASC 501, MASC 506.

514L Processing of Advanced Semiconductor Devices (3, Fa) Statistical design of experiments, vapor deposition of thin film dielectrics, plasma etching, advanced lithography, in-situ sensors, process monitoring, quality control, assurance/reliability. *Prerequisite:* EE 504.

518 Semiconductor Materials for Devices (3, Sp) Choice of materials systems, thermodynamics, kinetics and methods of bulk and epitaxial crystal growth of semiconductors and their alloys for electronic and optoelectronic devices. *Prerequisite:* an undergraduate course in semiconductor device physics or MASC 501 as a corequisite.

521 Corrosion Science (3) Chemical thermodynamics of corrosion; electrochemical mechanisms; kinetics of electrode reactions; passivity; galvanic couples; localized corrosion; stress corrosion cracking; corrosion fatigue; corrosion inhibition; atmospheric corrosion.

522 Corrosion Technology (3) Corrosion monitoring and control; anodic and cathodic protection; protective coatings; corrosion inhibitors; alloying; surface modification. *Prerequisite:* MASC 521.

523 Principles of Electrochemical Engineering (3) Electrochemical techniques; mass, charge, and heat transfer; electrochemical thermodynamics and electrode kinetics; electrochemical reactors; optimization; materials and corrosion; experimental modeling of industrial processes.

524 Techniques and Mechanisms in Electrochemistry (3) Modern electrochemistry; in-situ techniques; in-situ probes of the near-electrode region; ex-situ emersion techniques; cyclic voltammetry, electroxidation, electrochemical reduction, reactive film formation, enzyme electrochemistry.

534 Materials Characterization (3, Fa) Characterization of solids by optical microscopy, electron microscopy, (TEM, SEM) and elemental and structural analysis (EPMA, ESCA, AES, SIMS, HEED, LEED, SED, etc.).

535 Analytical Electron Microscopy (3) Specimen-electron beam interactions; electron diffraction and image formation of thin crystals. Kinematic and dynamic theory; scanning techniques; convergent beam diffraction; microanalysis; specialized techniques.

536L Analytical Electron Microscopy Laboratory (3) Introduction to transmission electron microscopy; instrument calibration; image dislocations; precipitates; grain boundaries and stacking faults; lattice fringe imaging; microanalysis by X-ray and electron spectroscopy. Project. *Prerequisite:* MASC 535.

539 Engineering Quantum Mechanics (3) (Enroll in EE 539)

548 Rheology of Liquids and Solids (3) (Enroll in CHE 548)

559 Creep (3) (Enroll in ME 559)

560 Fatigue and Fracture (3) (Enroll in ME 560)

561 Dislocation Theory and Applications (3, Sp) Elasticity theory; types, sources, motion, interaction of dislocations; stress fields and strain energies; partial dislocations and stacking faults; principles of work-hardening.

563 Dislocation Mechanics (3) Athermal and thermally-activated flow; deformation mechanisms; strengthening processes; solid solution and dispersion hardening; effect of impurity clouds; ordering phenomena; diffusion-controlled processes. *Prerequisite:* MASC 561.

564 Composite Materials (3, Fa) Fundamental and applied aspects of composites, with emphasis on basic mechanics, fracture, and failure criteria. Includes materials issues and fabrication technology.

583 Materials Selection (3) (Enroll in ME 583)

584 Fracture Mechanics and Mechanisms (3) (Enroll in ME 584)

590 Directed Research (1-12) Research leading to the master's degree. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

594abz Master's Thesis (2-2-0) For the master's degree. Credit on acceptance of thesis. Graded IP/CR/NC.

598 Materials Science Seminar (1) Seminar in Materials Science research. To be taken only once for graduate credit.

599 Special Topics (2-4, max 9)

601 Semiconductor Devices (3) (Enroll in EE 601)

606 Nonequilibrium Processes in Semiconductors (3, Sp) (Enroll in EE 606)

607 Electronic and Optical Properties of Semiconductor Quantum Wells and Superlattices (3) Quantum well potential and particle confinement, electron-electron, electron-phonon, and electron-impurity interactions, transport, magneto-transport, optical and magneto-optical properties, collective modes. *Prerequisite:* MASC 501, MASC 506.

610 Molecular Beam Epitaxy (3) Basic principles, ultra high vacuum, machine considerations, source purity and calibrations temperature measurements, surface morphology and chemistry, growth procedures, III-V, II-VI and silicon MBE. *Prerequisite:* MASC 501, MASC 503.

690 Directed Research (1-4, max 8) Laboratory study of specific problems by candidates for the degree Engineer in Materials Science. Graded CR/NC.

790 Research (1-12) Research leading to the doctorate. Maximum units which may be applied to the degree to be determined by the department. Graded CR/NC.

794abcdz Doctoral Dissertation (2-2-2-2-0) Credit on acceptance of dissertation. Graded IP/CR/NC.

Mechanical Engineering

Faculty
See the Aerospace and Mechanical Engineering section for the faculty list.

Degree Requirements

Bachelor of Science in Mechanical Engineering

The requirement for the degree is 128 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in mechanical engineering. See also general education in the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
ME 101L*	Introduction to Mechanical Engineering and Graphics	3
WRIT 140*	Writing and Critical Reasoning	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
MATH 126	Calculus II	4
ME 150L	Introduction to Computational Methods in Mechanical Engineering	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
General education	Social Issues	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
AME 203	Mechanics I	5
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		17

SECOND YEAR, SECOND SEMESTER		UNITS
AME 205	Mechanics II	5
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		17

THIRD YEAR, FIRST SEMESTER		UNITS
AE 309	Fluid Dynamics	4
AME 341aL	Mechoptronics Laboratory I	3
MASC 310	Mechanical Behavior of Materials	3
ME 310	Engineering Thermodynamics I	3
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 341bL	Mechoptronics Laboratory II	3
ME 331	Heat Transfer	3
ME Core Electives***		6
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
AME 400	Senior Seminar	1
ME 404	Mechanical Engineering Problems	3
ME 441aL	Experimental Engineering	3
ME 451	Linear Control Systems Analysis	3
ME Design Elective****		3
Technical Elective		3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
ME 409	Senior Design Project	4
ME 441bL	Experimental Engineering	3
Technical Electives		3
WRIT 340	Advanced Writing	3
General education		4
		17
Total units:		130

*Taken concurrently.

**Satisfies general education.

***Any upper division course in Mechanical Engineering.

****An approved ME design course (select from ME 408, ME 430, or any special topic design course).

Bachelor of Science in Mechanical Engineering (Petroleum Engineering)

The requirement for the degree is 131 units. A GPA of C (2.0) or higher is required in all upper division courses taken in the Department of Mechanical Engineering. See also the common requirements for undergraduate degrees section, page 458.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
ME 101L*	Introduction to Mechanical Engineering and Graphics	3
WRIT 140*	Writing and Critical Reasoning	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
MATH 126	Calculus II	4
ME 150L	Introduction to Computational Methods in Mechanical Engineering	4
PHYS 151L**	Fundamentals of Physics I: Mechanics, Waves and Sounds	4
General education		4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
AME 203	Mechanics I	5
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		17

SECOND YEAR, SECOND SEMESTER		UNITS
AME 205	Mechanics II	5
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		17

THIRD YEAR, FIRST SEMESTER		UNITS
AE 309	Fluid Dynamics	4
AME 341aL	Mechoptronics Laboratory I	3
ME 310	Engineering Thermodynamics I	3
PTE 463L	Introduction to Transport Processes in Porous Media	3
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
AME 341bL	Mechanical Laboratory II	3
ME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
ME 451	Linear Control Systems I	3
PTE 464L	Petroleum Reservoir Engineering	3
ME Core Elective***		3
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
AME 400	Senior Seminar	1
ME 404	Mechanical Engineering Problems	3
ME 408	Computer-Aided Design of Mechanical Systems	3
ME 441aL	Experimental Engineering	3
PTE 461	Formation Evaluation	3
PTE 465L	Drilling Technology and Subsurface Methods	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
ME 409	Senior Design Project	4
ME 441bL	Experimental Engineering	3
WRIT 340	Advanced Writing	3
Technical Elective		3
General education		4
		17
Total units:		130

*Taken concurrently.

**Satisfies general education Category III.

***Any upper division course in ME.

Bachelor of Science in Mechanical Engineering (Manufacturing Engineering)

If a student chooses six courses (9 to 18 units) from a prescribed program, he or she may graduate with the special designation Area of Emphasis in Manufacturing Engineering on the transcript. Details are given under Manufacturing Engineering on page 524.

Minor in Music Recording

A minor in music recording is offered through the School of Music to provide undergraduate students with the background necessary to enter the field of recording engineering and to familiarize them with the design needs of modern recording equipment. The minor is recommended to mechanical engineering majors with extensive musical training who would like to combine their technical and musical abilities while learning the engineering applications of physical and mathematical principles to the art of music recording. See the listing under the USC School of Music, page 665.

Master of Science in Mechanical Engineering

Requirements for the Master of Science in Mechanical Engineering are the same as set forth in the general requirements. Six of the required units must be in ME 525 and ME 526 or courses in engineering analysis approved in advance in writing by the Department of Mechanical Engineering.

The specific sequence of courses that constitutes an acceptable program must be approved in advance.

Requirements for Graduation Without Thesis, 27 units total with 3.0 GPA: ME 525 and 526 or approved mathematics (6); 500 level courses in major department (12); approved 400 or 500 level courses (9).

With Thesis, 27 units total with 3.0 GPA: ME 525 and 526 or approved mathematics (6); 500 or 600 level courses in major department (12) not including thesis; maximum ME 594ab — thesis (4); approved 400 or 500 level units (5) (a maximum total of eight units combining ME 590 and 594ab).

Recommended Programs of Study

The program of study depends upon the student's interest and background. Listed below

are eight areas in mechanical engineering with specific courses identified. Courses in other combinations and from other departments within the university may be approved if a particular coordinated interest can be demonstrated. In some instances students whose undergraduate background is not in mechanical engineering may be required to take additional course work.

During the first semester at USC, students must consult a departmental faculty advisor in the area of concentration and draw up an approved study plan.

Combustion and Propulsion Required courses: ME 436, 513, 514

Continuum Mechanics Required courses: ME 509, 510

Controls and Guidance Required courses: ME 451, 524, 541, 542

Design Methodology Required courses: ME 410, 503, 509, 541

Dynamics and Vibrations Required courses: ME 521, 522, 523, 524

Fluid Dynamics Required courses: ME 457, 518, 519

Heat Transfer Required courses: ME 457, 515, 516, 517

Intelligent Design Systems Required courses: ME 410, 505

Stress Analysis and Materials Required courses: ME 509, 559, 584

Master of Engineering in Computer-Aided Engineering
The Master of Engineering program educates and trains multidisciplinary professionals in the use of computational techniques in the planning, design and management of engineering projects. The emphasized computer-aided engineering subjects are modeling, simulation, visualization, optimization, artificial intelligence and advanced design, documentation, manufacturing and information management. The program provides the graduate with advanced education in a particular engineering subject area, associated with aerospace, civil or mechanical engineering. This advanced engineering education is coupled with an intensive concentration in computational procedures appropriate for that subject area. The Master of Engineering program also includes substantial project work to provide a background in the application of CAE techniques in real world situations. See the listing under Computer-Aided Engineering, page 494.

Engineer in Mechanical Engineering
Requirements for the Engineer in Mechanical Engineering degree are the same as set forth in the general requirements. Six of the units required for the degree must be ME 690. Prior approval must be obtained from the committee before registration in ME 690.

Doctor of Philosophy in Mechanical Engineering
The Doctor of Philosophy in mechanical engineering is also offered. See general requirements for graduate degrees.

Certificate in Computer-Aided Engineering
The Certificate in Computer-Aided Engineering is a limited version of the Master of Engineering in Computer-Aided Engineering program. It is designed to focus on providing an understanding of the overall field of computer-aided engineering. It includes a course covering the necessary computer science skills and a course introducing basic simulation techniques used in computer-aided engineering. In addition, the certificate provides knowledge in the use of CAE tools in a project environment. See the listing under Computer-Aided Engineering, page 495.

Courses of Instruction

MECHANICAL ENGINEERING (ME)

The terms indicated are *expected* but are not *guaranteed*. For the courses offered during any given term, consult the *Schedule of Classes*.

101L Introduction to Mechanical Engineering and Graphics (3, Fa) Gateway to the bachelor of science degree in mechanical engineering. Introduction to mechanical engineering disciplines and practice; graphical communication and layout of machine parts; introduction to computer-aided drafting and drawing.

150L Introduction to Computational Methods in Mechanical Engineering (4, Sp) Computer programming; organization of problems for computational solution; introduction to software for computation and graphics; applications to mechanical engineering problems. *Corequisite:* MATH 125.

201 Statics (3, Fa) Analysis of forces acting on particles and rigid bodies in static equilibrium; equivalent systems of forces, friction, centroids and moments of inertia; introduction to energy methods. *Prerequisite:* PHYS 151*L*, MATH 125.

204 Strength of Materials (3, Sp) Stress, strain and deflection of torsion members, beams in shear and bending, column and combined loads; energy methods, statically indeterminate structures; design of mechanical elements. *Prerequisite:* ME 201.

301 Dynamics (3, Fa) Particle and rigid body dynamics in two and three dimensions; concept of dynamic equilibrium and techniques of solution, including energy methods; introduction to vibrations. *Prerequisite:* ME 201.

302 Design of Dynamic Systems (3, Sp) Modeling of lumped parameter elements and systems; free and forced response of first and second order systems; design oriented approach to dynamic systems; microelectromechanical systems. *Recommended preparation:* MATH 245, AE 309, AME 205.

303 Dynamics of Machinery (3, Sp) Kinematics, inertia effects, and balancing of rotating and reciprocating machine parts; gyroscopic effects; critical speeds; energy variation in machinery; design of mechanisms. *Prerequisite:* AME 205.