USC Viterbi School of Engineering

In the school's state-of-the-art laboratories, aerospace and mechanical engineering students are reengineering this dissected Air Force Jet into a full flight simulator. Programs like these have propelled the school to its 2006 U.S. News & World Report *ranking as the seventh best graduate school in engineering.*

C ourses in engineering were first offered in 1906 in the basement of one of the oldest buildings on campus. Today, 165 full-time faculty serve about 1,800 undergraduates and 3,300 graduate students, utilizing state-of-the-art laboratories, classrooms, and live interactive high-speed Internet broadcast systems. The USC Andrew and Erna Viterbi School of Engineering's research program of over $147 million per year is funded through strong ties with government and industry.

The Viterbi School of Engineering seeks 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 Viterbi 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.

Administration
Yannis C. Yortsos, Ph.D., *Interim Dean*

Margaret Dufford, M.B.A., *Senior Associate Dean*

Randolph Hall, Ph.D., *Senior Associate Dean*

Herbert Schorr, Ph.D., *Senior Associate Dean*

Margery Berti, A.B., *Associate Dean*

Susan Lewis, M.B.A., *Associate Dean*

Louise A. Yates, B.A., M.S., *Associate Dean*

Degrees and Requirements

The Viterbi School of Engineering offers the following undergraduate curricula leading to the Bachelor of Science in: Aerospace Engineering, Applied Mechanics, Astronautical Engineering, Biomedical Engineering, Biomedical (Electrical Engineering), 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), Civil Engineering (Information Management); Computer Engineering and Computer Science, Computer Science, Electrical Engineering, Electrical Engineering (Computers), Environmental Engineering, Industrial and Systems Engineering, Information Systems Engineering, Mechanical Engineering, and Mechanical Engineering (Petroleum Engineering); and minor programs in Computer Science, Construction Planning and Management, Law and Internet Technology, Multimedia and Creative Technologies, Environmental Engineering, Petroleum Engineering and Polymer Science, Interactive Multimedia, Engineering Management, Materials Science, Video Game Design and Management, Video Game Programming, Web Technology and Applications, and 3-D Animation.

Graduate curricula leading to the Master of Science in: Aerospace Engineering, Applied Mechanics, Astronautical Engineering, 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, Mechanical Engineering (Dynamics and Control), Medical Device and Diagnostic Engineering, Operations Research Engineering, Petroleum Engineering, Petroleum Engineering (Smart Oilfield Technology), Product Development Engineering, Systems Architecture and Engineering, and System Safety and Security.

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

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

Graduate curricula leading to the Master of Engineering in: Environmental Quality Management, Structural Design.

Graduate curricula 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: Biomedical (Electrical Engineering), 133 units; Biomedical (Mechanical Engineering), 132 units; Chemical Engineering, 132 units; Chemical Engineering (Biochemical Engineering), 136 units; Chemical Engineering (Environmental Engineering), 134 units; Chemical Engineering (Petroleum Engineering), 136 units; Chemical Engineering (Polymer Science), 136 units; Civil Engineering, 131 units; Civil Engineering (Building Science), 135 units; Civil Engineering (Environmental Engineering), 130 units; Electrical Engineering, 131 units; Environmental Engineering, 132-134 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 program requires six courses in different categories, plus writing and diversity requirements, which together comprise the USC Core. See pages 60 and 219 for more information. In addition, students pursuing a degree in computer science must meet the foreign language requirement described on page 222.

The Provost has allowed an exception to the rules governing the general education program for students in the Viterbi 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 a score of 4 or 5 on the Advanced Placement U.S. history exam.

Students in the engineering "3-2" program are not required to satisfy general education 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. All students must, however, complete the WRIT 340 requirement.

Students in aerospace and mechanical engineering complete Social Issues and WRIT 130 in different semesters.

In all other respects, students in the Viterbi School of Engineering must satisfy the general education requirements as described on pages 60 through 219.

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 Viterbi School of Engineering requires that students complete all upper division units required for the major in residence.

For students in the Viterbi 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.

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 Viterbi Admission and Student Affairs Office. Academic Review Advisement forms may be obtained from Tutor Hall of Engineering (RTH) 110 or JHH 113.

Students on probation are encouraged to utilize the academic services provided by the Viterbi Admission and Student Affairs Office (advisement and free tutoring).

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 Admission and Student Affairs Office

The Viterbi Admission and Student Affairs Office, located in Ronald Tutor Hall of Engineering (RTH) 110, 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.

Center for Engineering Diversity

The Center for Engineering Diversity (CED) 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.

Contact the Center for Engineering Diversity 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.

Viterbi Career Services

The Viterbi School of Engineering provides extensive career services to its students. Students are encouraged to register with Viterbi 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 Viterbi 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, Accenture, 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.

Engineering Mentoring Program

To ease the transition from high school to college, the Viterbi 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 Viterbi School of Engineering has developed agreements 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 Viterbi 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 summer the Viterbi School of Engineering sponsors a seven-week academic program in either London, Paris, Madrid, Rome or other locations which provides students with the opportunity to enroll in engineering and humanities courses, as well as participate in a directed studies project. This program is open to all engineering majors.

Honor Societies

The Viterbi 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 Viterbi School of Engineering is under the jurisdiction of the Viterbi 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 Viterbi School of Engineering recommends candidates for the Master of Science degree in aerospace, astronautical engineering, biomedical, biomedical (biomedical imaging), chemical, civil, electrical, engineering management, environmental, industrial and systems, manufacturing, materials, mechanical, mechanical (dynamics and

control), ocean and petroleum engineering, applied mechanics, computer engineering, computer science, operations research, materials science, systems architecture and engineering, and system safety and security.

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 Viterbi 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 Viterbi 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 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 Viterbi 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 Viterbi 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 Master of Engineering Degree
The Master of Engineering is a highly-focused program in an industry-relevant area. It emphasizes applied solutions to real world problems. Courses selected for M.Eng. programs typically prepare the student for professional engineering practice beyond the purely scientific and technological course work for the M.S. degree. The program is intended for students directly from undergraduate engineering programs or for retraining practicing engineers who want to change career paths or technical areas. It is primarily for those not interested in earning a Ph.D. The M.Eng. is not a terminal degree, however, and courses applied toward the M.Eng. can also be applied toward the Ph.D. The M.Eng. requires an applied project or required design course for 3-6 units.

The Master of Engineering is awarded under the jurisdiction of the Viterbi School of Engineering.

Prerequisites
The prerequisites for Master of Engineering degrees are: a bachelor's degree in engineering, science or mathematics from a regionally accredited institution with satisfactory GPA and GRE scores; application for admission to the Viterbi School of Engineering; and acceptance by the appropriate department.

Course Requirements
The Master of Engineering requires a minimum of 30 units of graduate course work; up to 9 units at the 400 level may be counted with advisor approval and the remaining units must be at the 500 level or higher. The course work must form a coherent program of study with a concentration in core courses and restricted electives in core-related disciplines. The program will include an original project (directed research) or a design course for 3-6 units under the supervision of full-time or co-supervision of full-time and part-time faculty. The project or design course must require a final report and either a formal seminar, a presentation, or an oral examination by the student.

Grade Point Average Requirement
A minimum grade point average of 3.0 (A= 4.0) must be earned on all course work applied toward the M.Eng. degree. This average must also be achieved on all 400 level and above course work attempted at USC beyond the bachelor's degree, regardless of whether or not all such units are applied toward the degree. A minimum grade of C (2.0) is required in each course to receive graduate credit. Work graded C- or below is not accepted for subject or unit credit toward any graduate degree but will be calculated in the overall GPA. A maximum of four advisor approved units may be transferred from another institution with advisor approval.

Residence Requirements
A candidate must complete at least 26 of the 30 units for the M.Eng. at USC.

Time Limit
The time limit for completing the M.Eng. is five years from the first course until all requirements are met. An extension of up to two additional years may be granted by the Dean of the Viterbi School of Engineering.

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

Admission to the Doctor of Philosophy Program
Students in the M.Eng. program may still elect to undertake a Doctor of Philosophy program. A regular application for admission and supporting documents must be filed with the Office of Admission. Courses applied toward the M.Eng. may also be applied toward the course requirements of the Ph.D.

General Requirements for the Engineer Degree

The Engineer degree is awarded under jurisdiction of the Viterbi 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 a terminal degree. Students who complete the Engineer degree will not be considered for admission to the Ph.D. program.

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 Viterbi 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 Viterbi 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 Viterbi 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.

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 Viterbi 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 Viterbi 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.

102ab Engineering Freshman Academy (1-1, FaSp) Introduction to the profession of engineering. Ethical and societal consequences of engineering innovation and the impact of engineers on society. Team project and guest lectures. Open to freshmen only. Graded CR/NC.

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

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.

400 Engineering Honors Project (1-3, max 12, FaSpSm) Supervised interdisciplinary studies and projects. Enrollment limited to members of the Viterbi School of Engineering Honors Program. Graded CR/NC.

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

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

501x Technical Writing and Communication for Graduate Students in Engineering and Science (3, FaSp) Writing of theses proposals, conference papers, journal articles. Emphasis on structure of discourse and writing process. Presentation and communication skills also addressed. Students' own work used as course content. Not available for degree credit for master's or certificate students.

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 511L, and ME 583.

Aerospace and Mechanical Engineering

Aerospace Engineering Headquarters:
Robert Glenn Rapp Engineering Research Building 101
(213) 740-5353
FAX: (213) 740-7774
Email: ame@usc.edu

Mechanical Engineering Headquarters:
Olin Hall of Engineering 430
(213) 740-0484
FAX: (213) 740-8071
Email: ame@usc.edu

Chair: Michael E. Kassner, Ph.D.

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

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

William E. Leonhard Professorship in Engineering: Terence G. Langdon, Ph.D. (*Materials Science and Geological Sciences*)

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

Professors: Ron F. Blackwelder, Ph.D.*; Frederick K. Browand, Ph.D.; Charles Campbell, Ph.D.; Julian Domaradzki, Ph.D.**; Marijan Dravinski, Ph.D.; Fokion Egolfopoulos, Ph.D.; Henryk Flashner, Ph.D.; Roger Ghanem, Ph.D. (*Civil Engineering*); Mike Gruntman, Ph.D. (*Astronautics*); Michael E. Kassner, Ph.D., Joseph Kunc, Ph.D. *(Astronautics; 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.**; E. Phillip Muntz, Ph.D.** *(Radiology);* Paul K. Newton, Ph.D.; Steven Nutt, Ph.D. *(Materials Science);* Larry G. Redekopp, Ph.D.*; Paul Ronney, 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)*; Bingen Yang, Ph.D.

Associate Professors: Daniel Erwin, Ph.D.* *(Astronautics)*; Yan Jin, Ph.D.; Geoffrey R. Shiflett, Ph.D.*; Geoffrey Spedding, Ph.D.; Hai Wang, Ph.D.

Assistant Professors: Denis Phares, Ph.D.; Tait Pottebaum, Ph.D.

Adjunct Professors: John McIntyre, Ph.D.; M. Oussama Safadi, Ph.D.; Eugene H. Trinh, Ph.D.

Research Associate Professors: Jianbang Liu, Ph.D.; Adam Fincham, Ph.D.; Hussein Youssef, Ph.D.

Research Assistant Professors: Mohamed Abid, Ph.D.; Sergey Gimelshein, Ph.D.; Andrew Ketsdever, Ph.D.; Xianming Liu, Ph.D.; Maria Teresa Perez Prado, Ph.D.; Steve Wojtkiewicz, Jr., Ph.D.

Research Associates: Mustafa Andac, Ph.D.; Peter Diamessis, Ph.D.; Hongli Ding, Ph.D.; Yufei Dong, Ph.D.; Janet Tew Hallett, Ph.D.; Chiaoying Jiao, Ph.D.; Phailaung Phohomsiri, Ph.D.; Youngjin Son, Ph.D.; Cheng Xu, 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

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

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

(2) The undergraduate curriculum will cover both fundamental and applied sciences to prepare students 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 non-technical backgrounds.

Aerospace Engineering Degrees

Bachelor of Science in Aerospace Engineering
The requirement for this degree is 128-129 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 the common requirements for undergraduate degrees section, page 518.

FIRST YEAR, FIRST SEMESTER		UNITS
AME 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
General education	Social Issues	4
		16

FIRST YEAR, SECOND SEMESTER		UNITS
AME 150L	Introduction to Computational Methods	4
MATH 126	Calculus II	4
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics	4
WRIT 130	Analytical Writing	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
AME 201	Statics	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
AME 204	Strength of Materials	3
AME 261	Basic Flight Mechanics	4
ASTE 280	Astronautics and Space Environment I	3
MATH 245	Mathematics of Physics and Engineering I	4
		14

THIRD YEAR, FIRST SEMESTER		UNITS
AME 301	Dynamics	3
AME 310	Engineering Thermodynamics I	3
AME 341aL	Mechoptronics Laboratory I	3
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 309	Dynamics of Fluids	4
AME 341bL	Mechoptronics Laboratory II	3
General education		4
Free electives**		1-2
		15-16

FOURTH YEAR, FIRST SEMESTER		UNITS
AME 404	Computational Solutions to Engineering Problems	3
AME 441aL	Senior Projects Laboratory	3
AME 451	Linear Control Systems I	3
Electives	AE Core***	6
Elective	Technical****	3
		18

FOURTH YEAR, SECOND SEMESTER		UNITS
AME 481	Aircraft Design, or	4
ASTE 420**	Spacecraft Design	3
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.

**Students planning to take ASTE 420 must take two units of free electives in order to earn a total of 128 units.

***Any upper division AME courses.

****Technical electives consist of (1) any upper division course in engineering except CE 404, CE 412 and ISE 440, 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.

Accelerated Dual Degree Program: Bachelor of Science/Master of Science in Aerospace Engineering

The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to six units of course work will be counted toward satisfying the unit requirements of both programs. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

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 that comprise these core and elective requirements is available from the department.

M.S., Aerospace and Mechanical Engineering (Computational Fluid and Solid Mechanics)

The program prepares students for professional careers in engineering companies that develop products using computational tools of fluid and solid mechanics. The program also provides the necessary background for pursuing higher degrees, Engineer and Ph.D., in aerospace and mechanical engineering with specializations in computational fluid mechanics, computational solid mechanics and computational heat transfer. The degree course work provides a necessary background in basic aerospace and mechanical engineering disciplines (solid mechanics, fluid mechanics, heat transfer), engineering mathematics and numerical methods. The capstone project courses, AME 535b and CE 551, provide practical examples using existing numerical programs to simulate structures, heat transfer and fluid flows as well as commercial mathematical packages for analyzing data.

Admission requirements follow the general admission rules for aerospace and mechanical engineering graduate programs. The program requires completion of a minimum of 27 units and a cumulative GPA of at least 3.0 for graduation. The program with thesis requires 28 units, four of which are to be with thesis.

REQUIRED CORE COURSES (24 UNITS)		UNITS
AME 404	Computational Solutions to Engineering Problems	3
AME 509	Applied Elasticity, or	
CE 507	Mechanics of Solids I	3
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3
AME 530a	Dynamics of Incompressible Fluids	3
AME 535a	Introduction to Computational Fluid Mechanics	3
AME 535b	Introduction to Computational Fluid Mechanics, or	
CE 551	Computer-Aided Engineering Project	3
CE 529a	Finite Element Analysis	3

Selected technical electives from the following list or other electives approved by a graduate advisor: 3 units.

TECHNICAL ELECTIVES		UNITS
AME 511	Compressible Gas Dynamics	3
AME 516	Convection Processes	3
AME 564	Computational Techniques in Rarefied Gas Dynamics	3
AME 590	Directed Research	1-12
AME 599	Special Topics	2-4, max 9
CE 529b	Finite Element Analysis	3
CE 541a	Dynamics of Structures	3
CE 542	Theory of Plates	3

One core class requirement may be waived at the discretion of a graduate advisor if a student documents that he or she completed or is enrolled in an equivalent course. The waived class must be replaced by a technical elective. Credit for one course of not more than 4 units from another accredited institution may be approved by a graduate advisor. The Master's Thesis (4 units) may be substituted for a technical elective class (3 units).

Master of Science in Product Development Engineering

See the listing under Product Development Engineering, page 610.

Master of Science in Systems Architecture and Engineering

See the listing under Systems Architecture and Engineering, page 612.

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 563.

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 AME 690. Prior approval must be obtained from the guidance committee before registration in AME 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 Computer-Aided Engineering
See listing on page 564.

Mechanical Engineering Degrees

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 518.

FIRST YEAR, FIRST SEMESTER		UNITS
AME 101L	Introduction to Mechanical Engineering and Graphics	3
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
General education	Social Issues	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
AME 150L	Introduction to Computational Methods	4
MATH 126	Calculus II	4
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics	4
WRIT 130	Analytical Writing	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
AME 201	Statics	3
MASC 310	Materials Behavior and Processing	3
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
General education		4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
AME 204	Strength of Materials	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
AME 301	Dynamics	3
AME 309	Dynamics of Fluids	4
AME 310	Engineering Thermodynamics I	3
AME 341aL	Mechoptronics Laboratory I	3
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 331	Heat Transfer	3
AME 341bL	Mechoptronics Laboratory II	3
AME Core Electives**		3
WRIT 340	Advanced Writing	3
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
AME 404	Computational Solutions to Engineering Problems	3
AME 442aL	Experimental Engineering	3
AME 451	Linear Control Systems Analysis	3
AME Design Elective***		3
Technical Elective		3
		15

FOURTH YEAR, SECOND SEMESTER		UNITS
AME 409	Senior Design Project	4
AME 442bL	Experimental Engineering	3
General education		4
AME Core Elective**		3
Technical Electives		3
		17
Total units:		128

*Satisfies general education.

**Any upper division course in AME.

***An approved AME design course (select from AME 408, AME 430, or any special topic design course).

Bachelor of Science in Mechanical Engineering (Petroleum Engineering)
The requirement for the degree is 128 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 518.

FIRST YEAR, FIRST SEMESTER		UNITS
AME 101L	Introduction to Mechanical Engineering and Graphics	3
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
General education	Social Issues	4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
AME 150L	Introduction to Computational Methods in Mechanical Engineering	4
MATH 126	Calculus II	4
PHYS 151L*	Fundamentals of Physics I: Mechanics, Waves and Sounds	4
WRIT 130	Analytical Writing	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
AME 201	Statics	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
AME 204	Strength of Materials	3
AME 310	Engineering Thermodynamics I	3
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
AME 301	Dynamics	3
AME 309	Dynamics of Fluids	4
AME 341aL	Mechoptronics Laboratory I	3
AME 463L	Introduction to Transport Processes in Porous Media	3
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 341bL	Mechanical Laboratory II	3
AME 451	Linear Control Systems I	3
PTE 464L	Petroleum Reservoir Engineering	3
AME Core Elective**		3
		15

FOURTH YEAR, FIRST SEMESTER		UNITS
AME 404	Computational Solutions to Engineering Problems	3
AME 408	Computer-Aided Design of Mechanical Systems	3
AME 442aL	Experimental Engineering	3
PTE 461	Formation Evaluation	3
PTE 465L	Drilling Technology and Subsurface Methods	3
		15

FOURTH YEAR, SECOND SEMESTER		UNITS
AME 331	Heat Transfer	3
AME 409	Senior Design Project	4
AME 442bL	Experimental Engineering	3
WRIT 340	Advanced Writing	3
General education		4
		17

Total units: 128

*Satisfies general education Category III.

**Any upper division course in AME.

Minor in Music Recording

A minor in music recording is offered through the 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 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 Thornton School of Music, page 733.

Accelerated Dual Degree Program: Bachelor of Science/Master of Science in Mechanical Engineering

The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to six units of course work will be counted toward satisfying the unit requirements of both programs. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

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 AME 525 and AME 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: AME 525 and AME 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: AME 525 and AME 526 or approved mathematics (6); 500 or 600 level courses in major department (12) not including thesis; maximum AME 594ab — thesis (4); approved 400 or 500 level units (5) (a maximum total of 8 units combining AME 590 and AME 594ab).

Recommended Programs of Study
The program of study depends upon the student's interest and background. During the first semester at USC, students must consult with a departmental faculty advisor in the area of concentration and draw up a plan of study, which must be approved by the advisor. Besides the common requirements, listed below are several areas in mechanical engineering with specific courses identified as core and core electives. Groups of 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 background is not in mechanical engineering may be required to take additional course work.

Common Requirements
Engineering Analysis (6 units): AME 525, AME 526

Engineering Electives (3-6 units): Approved 400-, 500- or 600-level courses

Engineering Design
Core courses (9 units): AME 503, AME 505, AME 509

Core electives (6 units): Two courses from AME 404, AME 527, AME 541, ASTE 520, ASTE 523, CE 529, SAE 549

Thermal and Fluid Sciences
Core courses (12 units): Four courses from one of the selected areas:

Combustion: AME 436, AME 513, AME 514, AME 530a

Fluid Dynamics: AME 457, AME 511, AME 530a, AME 535a

Heat Transfer: AME 457, AME 515, AME 516, AME 517

Core electives (6 units): Take two courses from the following list, not duplicating the above selection: AME 436, AME 457, AME 511, AME 513, AME 514, AME 515, AME 516, AME 517, AME 530a, AME 533, AME 535a, AME 535b, AME 537

Mechanics and Materials
Core courses (12 units): AME 509, AME 559, AME 560, AME 584

Core elective (3 units): One of AME 542, AME 588, CE 529a

Microelectromechanical Systems (MEMS)
Core courses (12 units): AME 455, AME 537, BME 551, EE 607

Core elective (3 units): One of AME 535a, ASTE 501a, ASTE 545

Dynamics and Control
Students interested in this area may follow the M.S., Aerospace and Mechanical Engineering (Dynamics and Control) described below.

Masters of Science in Aerospace and Mechanical Engineering (Dynamics and Control)
The Master of Science with emphasis in Dynamics and Control educates and trains multidisciplinary professionals in the modeling, analysis, simulation and control of complex time-evolutionary systems. It is a program of study that encompasses advanced analytical dynamics, nonlinear dynamical systems, linear and nonlinear dynamics and vibrations, and linear and nonlinear control. The program equips students to apply their knowledge to a variety of complex systems encountered in nature and society, especially those in civil, mechanical and aerospace engineering and applied mechanics.

Students will be given advisement in the first semester of their study. In addition to AME 525 and AME 526, students are required to take the following core courses: AME 521, AME 522, AME 524, AME 541, AME 552. Elective courses can be chosen in areas of specific interest to the student such as orbital dynamics, spacecraft control, aircraft dynamics and control, chaos and chaotic dynamics, random vibrations, computer control of mechanical systems and robotics. The program provides the graduate student with a broad, well-rounded, advanced education that can be applied to many specific, technologically advanced fields in which dynamics and control play a pivotal role.

Master of Science in Aerospace and Mechanical Engineering (Computational Fluid and Solid Mechanics)
See listing under Aerospace Engineering Degrees, page 527.

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 AME 690. Prior approval must be obtained from the committee before registration in AME 690.

Doctor of Philosophy in Mechanical Engineering
The Doctor of Philosophy in mechanical engineering is also offered. See general requirements for graduate degrees.

Courses of Instruction

AEROSPACE AND MECHANICAL ENGINEERING (AME)

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.

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 Computational Methods (4, Sp) Computer programming; organization of problems for computational solution; introduction to software for computation and graphics; applications to engineering problems. *Corequisite:* MATH 125.

201 Statics (3, FaSpSm) 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:* MATH 125; *recommended preparation:* AME 101, PHYS 151*L*.

204 Strength of Materials (3, FaSp) Stress, strain and deflection of mechanical elements due to tension, shear, bending, or torsion; combined loads; energy methods, statically indeterminate structures; strength-based design. *Prerequisite:* AME 201 or CE 205.

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. *Recommended preparation:* AME 150*L*.

291 Undergraduate Design Projects I (1, max 4, FaSpSm) Analysis, design, fabrication, and evalutation of devices intended for entry in local and national design competitions. Intended for lower division students or those with little prior project experience. Graded CR/NC.

301 Dynamics (3, FaSp) 2-D and 3-D kinematics and dynamics of particles and rigid bodies; systems of particles and rigid bodies; coupled rigid bodies; introduction to vibrations. *Prerequisite:* AME 201 or CE 205; *recommnded preparation:* PHYS 151*L*.

302 Dynamic Systems (3, FaSp) Modeling of lumped parameter elements and systems; free and forced response of first and second order systems; design oriented approach to dynamic systems. *Corequisite:* MATH 245; AME 309 or CE 309; AME 301 or CE 325.

303 Dynamics of Machinery (3, FaSp)
Kinematics and dynamics of machines; balancing of rotating and reciprocating machinery; gyroscopic effects; critical speeds; energy variation in machinery; introduction to mechanism design. *Prerequisite:* AME 301 or CE 325.

305 Mechanical Design (3, FaSp) Design and analysis of mechanical elements including shafts, bearings, springs, screws, belts and gears; strength, fatigue and deflection considerations in machine design. *Prerequisite:* AME 204 or CE 225.

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

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 310.

310 Engineering Thermodynamics I (3, FaSp) Fundamental laws of thermodynamics applied to actual and perfect gases and vapors; energy concepts, processes, and applications. Prerequisite: MATH 226; *recommended preparation:* PHYS 151*L*, high-level programming language.

312 Engineering Thermodynamics II (3, Sp) Application of thermodynamic principles to fluid flow, power cycles, and refrigeration. *Prerequisite:* AME 310; *recommended preparation:* high-level programming language.

331 Heat Transfer (3, Sp) General principles underlying heat transfer by conduction, convection, and radiation; steady flow and transient flow. *Prerequisite:* AME 310; *corequisite:* AME 309 or CE 309.

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. *Prerequisite:* PHYS 152*L*, MATH 126.

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.

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*.

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

403 Stress Analysis (3, Sp) Theories of failure, shear center, unsymmetrical bending, curved beams, torsion of non-circular sections; cylinders, rotating discs, thermal stresses, inelastic strains, energy methods. *Prerequisite:* AME 204.

404 Computational Solutions to Engineering Problems (3, Fa) Mathematical aspects of the solutions to typical advanced mechanical engineering problems. Modeling, simulation, computational aspects, computer solutions, and computational tools. *Recommended preparation:* FORTRAN, MATLAB and Maple.

406 Automotive Engines (3, Irregular) Analysis of performance and operating characteristics of automotive engines; discussion of carburetion, ignition, fuels, lubrication, and emissions. *Prerequisite:* AME 312.

408 Computer-Aided Design of Mechanical Systems (3, Fa) Design of mechanical systems using advanced graphics techniques; computer-aided drafting, design optimization, elements of computer graphics, solids modeling; introduction to computer-aided manufacturing.

409 Senior Design Project (4, Sp) Modeling, analysis, integration, layout and performance analysis of a mechanical system to meet specified design requirements. *Prerequisite:* senior standing.

410 Engineering Design Theory and Methodology (3, Fa) Product planning and task clarification, voice of customers, quality function deployment, conceptual and embodiment design, axiomatic theory of design, product quality and manufacturability, design decision-making. Junior standing. *Recommended preparation:* AME 305.

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

413 Fuels and Combustion Fundamentals (3, Irregular) Fuel properties related to combustion processes; fundamentals of combustion processes, standard combustion tests, and calculation of flame properties. Applications. *Prerequisite:* AME 312.

420 Engineering Vibrations I (3, Fa) Theory of free and forced vibrations with and without damping; systems of single and multiple degrees of freedom; iteration; methods; vibration isolation; instrumentation. *Prerequisite:* MATH 245.

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

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

430 Thermal Systems Design (3, Fa) Design methodology for thermal systems; boilers, condensers, air conditioning systems, power plants and other systems with thermal energy interaction. *Prerequisite:* AME 312 and AME 331.

431 Thermal Design and Analysis of Electronic Equipment (3, Irregular) Cooling problems in electronic equipment; convective cooling; extended surfaces; cold plates; phase-change methods; thermoelectric cooling; Peltier refrigeration. Application to space avionics and modern computers. *Prerequisite:* AME 331.

436 Energy and Propulsion (3, FaSm) Performance and analysis of reciprocating, jet, rocket engines, and hybrid systems. Characteristics of inlets, compressors, combustors, turbines, nozzles and engine systems. Energy and environmental problems. *Prerequisite:* AME 310; AME 309 or CE 309.

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

442abL Experimental Engineering (3-3, a: Fa; b: Sp) Experiments in: *a:* fluid flow, heat transfer, buckling, torsion, vibration; *b:* control of dynamic systems, feedback controller design and implementation using analog/digital computers. Technical reports: projects. Senior standing. *Prerequisite:* for *a*: AME 341b*L;* for *b:* AME 451.

451 Linear Control Systems I (3, FaSpSm) Transform methods, block diagrams; transfer functions; stability; root-locus and frequency domain analysis and design; state space and multiloop systems. *Prerequisite:* MATH 245.

452 Intermediate Kinematics (3, Irregular)
Analytical solutions to problems in rigid body kinematics. Complex number and matrix formulations; degrees of freedom and constraint; applications to mechanism synthesis. *Prerequisite:* senior or graduate standing.

453 Engineering Dynamics (3, Sp) Principles of dynamics applied to mechanical and aerospace problems. Introduction to gyroscopic motion and rigid body dynamics. *Prerequisite:* MATH 245.

454 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:* AME 353.

455 Introduction to MEMS (3, Sp) Introduction to micro-electro-opto-mechanical systems; scaling effects on material properties, fluid flows, dynamical behavior; fabrication methods; design considerations for MEMS sensors and actuators. *Recommended preparation:* AME 301, AME 309 and AME 310.

457 Engineering Fluid Dynamics (3, Fa) Laminar and turbulent boundary layer flow with and without heat transfer; boundary layer separation, stability, transition and control; introduction to compressible fluid flow. *Prerequisite:* AME 310; AME 309 or CE 309.

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

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

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

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

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

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

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

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

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

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.

480 Environmental Design and Control (3) Detailed analysis of psychometric, heat-transfer, and thermodynamic parameters affecting domestic, commercial and space environmental control; selection of equipment and instrumentation. Case studies. *Prerequisite:* AME 312, AME 331, and either AME 309 or CE 309.

481 Aircraft Design (4, Sp) Aircraft design and analysis, design requirements and specifications; integration of structure, propulsion, control system, and aerodynamic configuration; performance analysis and prediction. *Recommended preparation:* AME 309, AME 353.

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.

489 Numerical Methods in Engineering (3, Sp) Numerical techniques suitable for computer solution of roots of equations, integration, simultaneous algebraic equations, ordinary and partial differential equations, polynomial approximations, eigenvalue problems. *Prerequisite:* MATH 245; *recommended preparation:* FORTRAN or C programming.

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

491 Undergraduate Design Projects II (1, max 4, FaSpSm) Analysis, design, fabrication, and evaluation of devices intended for entry in local and national design competitions. Intended for students with prior project experience. Upper division standing. Graded CR/NC.

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

503 Advanced Mechanical Design (3, Fa) Specific problems and methods of analysis in mechanical systems design.

504 Metallurgical Design (3, Sp) Relationship between metallurgical and environmental factors and the behavior of materials. *Prerequisite:* AME 303.

505 Engineering Information Modeling (3, Sp) Symbolic and object-oriented modeling, product and process modeling for design and manufacturing, information models for computer integrated and collaborative engineering, information modeling for life-cycle engineering.

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

509 Applied Elasticity (3, Irregular) Condensed treatment dealing with engineering applications of the principles of elasticity, using the theories of elasticity, elastic stability, and plates and shells. *Prerequisite:* AME 403.

510 Introduction to Continuum Mechanics (3, Fa) Theories of continuous media such as linear and nonlinear theories of elasticities, theories of ideal, compressible and viscous fluids. *Prerequisite:* AME 525, AME 526.

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 Advanced Thermodynamics (3, Sp) Thermodynamics of irreversible processes; Onsager relations; kinetic theory; transport processes; statistical thermodynamics; ideal gas properties at high temperatures. *Corequisite:* AME 525 or AME 526.

513 Principles of Combustion (3, Sp) Thermochemistry, equilibrium, chemical kinetics, flame temperature, flame velocity, flame stability, diffusion flames spray combustion, detonation. Equations of motion including reaction, heat transfer, and diffusion.

514 Applications of Combustion and Reacting Flows (3) Advanced topics and modern developments in combustion and reacting flows including ignition and extinction, pollutant formation, microscale and micro-gravity combustion, turbulent combustion and hypersonic propulsion. *Prerequisite:* AME 513.

515 Advanced Problems in Heat Conduction (3, Sp) Review of analytical methods in heat conduction; moving boundaries melting and freezing; sources and sinks, anisotropic and composite media; numerical methods for steady and unsteady problems. *Prerequisite:* AME 526, AME 331.

516 Convection Processes (3, Fa) Analysis of isothermal and nonisothermal boundary layers. Exact and approximate solutions of laminar and turbulent flows. Variable-property and high-speed effects; dimensional analysis. *Prerequisite:* AME 457; *recommended preparation:* AME 526, AME 331.

517 Radiation Heat Transfer (3, Fa) Radiation properties; black body radiation; shape factors of radiation network analogy and solar radiation. *Prerequisite:* AME 331; *corequisite:* AME 525 or AME 526.

518 Engineering Gas Dynamics (3, Sp) Analysis of compressible flows; subsonic, supersonic flows; shock waves as flow discontinuities; shock structure; supersonic inlets. Effects of friction, heat transfer; chemical reaction. Shock-expansion. *Prerequisite:* AME 457.

519 Advanced Fluid Dynamics (3, Fa) Kinematics and dynamics of flow of continuous media; Navier-Stokes equations; simplifications, exact, and approximate solutions; irrotational flows; hydrodynamic stability; turbulence; free shear flows. *Prerequisite:* AME 457.

521 Engineering Vibrations II (3, Sp) Multi-degree of freedom systems; modal analysis. Rayleigh's quotient. Continuous systems; modal analysis. Beams, rods, membranes. Colocations, Galerkin, Rayleigh Ritz methods; finite elements. *Prerequisite:* AME 420.

522 Nonlinear Dynamical Systems, Vibrations, and Chaos (3, Sp) Lagrange equations; nonlinear maps and differential equations; fixed points; periodic motion; qualitative/quantitative and local/global analysis; higher order systems; stability; bifurcations; chaos; fractals. *Prerequisite:* AME 420, AME 524; *recommended preparation:* AME 525.

523 Random Vibrations (3, Irregular) Random processes, ergodic theory. Ito calculus. Linear systems under stationary and nonstationary excitations. Fokker-Planck equations. Failure analysis and first passage problems. *Prerequisite:* AME 420, basic probability (or MATH 407), AME 451 recommended.

524 Advanced Engineering Dynamics (3, Fa) Principle of virtual work, constraints, Lagrange's equations, Gibbs-Appell equations, Gauss's Principle, Theory of Rotations, dynamics of rigid bodies, Hamiltonian mechanics, Hamilton-Jacobi equation. *Recommended preparation:* AME 521, AME 525.

525 Engineering Analysis (3, Sp) Typical engineering problems discussed on a physical basis. Vector analysis; functions of complex variables, infinite series, residues.

526 Engineering Analytical Methods (3, Fa) Typical engineering problems discussed on a physical basis. Fourier series; Fourier integrals; Laplace transform; partial differential equations; Bessel function.

527 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.

528 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.

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.

530ab 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.

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

532ab 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:* AME 459.

533 Multi-Phase Flows (3, Sp) Physics of the interaction between phases, empirical and analytical methods of solution to relevant technological problems. *Prerequisite:* AME 457.

534 Lubrication, Friction, and Wear (3, Irregular) Theories of lubrication, friction, and wear; their application to the design of mechanical systems and components, including gears, bearings, clutches, and brakes.

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:* AME 525. *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:* AME 535*a*; AME 511 or AME 530*a*.

536 Rotating Fluid Machinery (3, Irregular) Aerodynamics of compressors and turbines; subsonic, transonic, and supersonic flow characteriscs; secondary flow and stall; stability; component matching of total engine; non-dimensional representation of performance. *Prerequisite:* AME 312, AME 457.

537 Microfluidics (3, Fa) Introduction to fluid dynamics in the microscale. Scaling parameters, dynamic, thermodynamic, electro-osmotic and electrochemical forces. Flow in microdevices, external flow measurement and control, microvalves and micropumps. Limited to students with graduate standing. *Recommended preparation:* AME 309, MATH 445.

540 Engineering Statistics (3, Fa) Definitions and concepts of statistics applied to mechanical testing and production: sampling, distributions, probability, variance, reliability, and quality control.

541 Linear Control Systems II (3, Fa) State space representation, linearization, solution of state equations; controllability and observability; state feedback, state observers; optimal control; output feedback. *Prerequisite:* AME 451.

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

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

544 Computer Control of Mechanical Systems (3, Sp) Computer control as applied to machine tools, mechanical manipulators, and other mechanical machinery; discrete time controller design; microprocessor implementation of motion and force control servos. *Prerequisite:* AME 451.

545 Modeling and Control of Distributed Dynamic Systems (3, Sp) Modeling and analysis of complex flexible mechanical systems; distributed transfer function synthesis; frequency-domain control methods; smart structure design; applications in vibration and noise control. *Prerequisite:* AME 521 and AME 541.

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:* AME 546.

548 Analytical Methods in Robotics (3, SpSm) Homogeneous transformations; formal description of robot manipulators; kinematic equations and their solution; differential relationships; dynamics; control; static forces; compliance. *Prerequisite:* EE 545; EE 482 or AME 451; knowledge of linear algebra.

549 Systems Architecting (3, FaSp) (Enroll in SAE 549)

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.

552 Nonlinear Control Systems (3, Sp) Phase plane, describing functions, applications to mechanical and aerospace systems. Lyapunov direct and indirect methods, applications; Popov circle criteria applications. *Prerequisite:* AME 541.

553abL Digital Control Systems (3-1) (Enroll in EE 543*abL*)

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:* SAE 549.

559 Creep (3, Sp) Behavior of engineering materials at elevated temperatures; thermal stresses; creep mechanisms; interpretation of creep data; methods of predicting long-term strains.

560 Fatigue and Fracture (3, Irregular) Behavior of materials under cyclic and static fatigue; plastic instability; life-time predictions; brittle and ductile fracture; crack propagation and plastic blunting.

561 Dislocation Theory and Applications (3) (Enroll in MASC 561)

563 Dislocation Mechanics (3) (Enroll in MASC 563)

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:* AME 511 or AME 531.

570ab Current Topics in Aerodynamics (3-3) Selected material of current engineering interest in aerospace engineering and related fields.

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

575 Advanced Engineering Analysis (3, Fa) Solution of engineering problems by methods of calculus variations, integral equations, asymptotic expansions. *Prerequisite:* CE 525*ab* or AME 525 and AME 526.

576 Advanced Engineering Analytical Methods (3, Sp) Solution of engineering problems by methods of linear and nonlinear partial differential equations of first and second order; perturbations. *Prerequisite:* CE 525*ab* or AME 525 and AME 526.

584 Fracture Mechanics and Mechanisms (3, Fa) Failure modes, stress concentrations, complex stress analysis, linear elastic fracture mechanics, yielding fracture mechanics, experimental methods, environmental assisted fracture and fatigue. *Prerequisite:* AME 403.

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:* ASTE 535, AME 486.

588 Materials Selection (3, Sp) Materials selection in relationship to design and fabrication, economic considerations, methodology of selection, performance parameter; case studies.

589x Management for Engineers (4, Irregular) Fundamentals of Project Management, interpersonal management, technology and market assessment; multiple perspective analysis; decision making based on qualitative and quantitative data. Not open for credit to majors in Industrial and Systems Engineering.

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 mechanical 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:* AME 526 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:* AME 530*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:* AME 530*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:* AME 526.

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:* AME 526.

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:* AME 530*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:* AME 530*b*.

690 Directed Research (1-4, max 8) Laboratory study of specific problems by candidates for the degree Engineer in Mechanical 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.

Applied Mechanics

Email: civileng@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 and Mechanical Engineering and Civil Engineering. Students may register in either of these two departments and still qualify for this degree. See common requirements for undergraduate degrees section, page 518.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL	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
MATH 126	Calculus II	4
PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics	4
Electives	Approved electives in computer programming	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
AME 310	Engineering Thermodynamics I	3
CE 325	Dynamics	3
EE 326L	Essentials of Electrical Engineering	4
MATH 445	Mathematics of Physics and Engineering II	4
		14

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

FOURTH YEAR, FIRST SEMESTER		UNITS
AME 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 556.

Astronautics and Space Technology

Robert Glenn Rapp Engineering Research Building (RRB) 230
(213) 821-5817
FAX: 213-821-5819
Email: astd@usc.edu

Chair: Mike Gruntman, Ph.D.

Faculty
IBM Chair in Engineering Management: F. Stan Settles, Ph.D

Professors: Mike Gruntman, Ph.D. (*Aerospace Engineering*); Darrell L. Judge, Ph.D. (*Physics and Astronomy*); Joseph A. Kunc, Ph.D. (*Physics and Astronomy, Aerospace Engineering*)

Associate Professor: Daniel A. Erwin, Ph.D.* (*Aerospace Engineering*)

Adjunct Professors: Robert Brodsky, Ph.D.; Gerald Hintz, Ph.D.; James Wertz, Ph.D.

Research Professor: Peter M. Will, Ph.D. (*Industrial and Systems Engineering, Materials Science*)

Research Assistant Professor: Andrew Ketsdever, Ph.D. (*Aerospace and Mechanical Engineering)*

*Recipient of university-wide or school teaching award.

Aerospace Engineering Honor Society: Sigma Gamma Tau

Degree Requirements

Bachelor of Science in Astronautical Engineering

The Bachelor of Science in Astronautical Engineering prepares students for engineering careers in the space industry, for research and development in industry and government centers and laboratories, and for graduate study. The program combines a core in the fundamentals of engineering, specialized work in astronautics and space technology, and technical electives to broaden and/or deepen the course work.

This degree requires the completion of 128 units. A grade point average of C (2.0) or higher is required in all upper division Astronautical Engineering courses. See also the common requirements for undergraduate engineering degrees section, page 518.

REQUIRED LOWER DIVISION COURSES		UNITS
AME 150L	Introduction to Computational Methods	4
AME 201	Statics	3
AME 204	Strength of Materials	3
ASTE 101L	Introduction to Astronautics	4
ASTE 280	Astronautics and Space Environment I	3
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MATH 125	Calculus I	4
MATH 126	Calculus II	4

MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
WRIT 130	Analytical Writing	4

REQUIRED UPPER DIVISION COURSES		UNITS
AME 301	Dynamics	3
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 341abL	Mechoptronics Laboratory	3-3
AME 404	Computational Solutions to Engineering Problems	3
AME 441aL	Senior Projects Laboratory	3
ASTE 301ab	Thermal and Statistical Systems	3-3
ASTE 330	Astronautics and Space Environment II	3
ASTE 420	Spacecraft Design	3
ASTE 470	Spacecraft Propulsion	3

ASTE 480	Spacecraft Dynamics	3
WRIT 340	Advanced Writing	3
Elective	Technical elective**	15
Total Units		107

*Satisfies general education Category III.

**Technical electives consist of (1) any upper division course in engineering except CE 404, CE 412 and ISE 440, 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.

Minor in Astronautical Engineering

This program is for USC students who wish to work in the space industry and government space research and development centers and who are pursuing bachelor's degrees in science, mathematics or engineering with specializations other than in astronautical engineering.

The space industry employs a wide variety of engineers (electrical, mechanical, chemical, civil, etc.); scientists (physicists, astronomers, chemists); and mathematicians. These engineers participate in development of advanced space systems but they usually lack the understanding of basic fundamentals of astronautics and space systems. The minor in astronautical engineering will help overcome this deficiency and provide unique opportunities for USC engineering, science and mathematics students, by combining their basic education in their major field with the industry-specific minor in astronautical engineering.

Required coursework consists of a minimum of 18 units of course work. Including prerequisites, the minor requires 38 units. Three courses, or 9 units, at the 400 level will be counted toward the minor degree. The course work is a balanced program of study providing the basic scientific fundamentals and engineering disciplines critically important for contributing to development of complex space systems.

Prerequisite courses: MATH 125, MATH 126 and MATH 226; PHYS 151L and PHYS 152L.

REQUIRED COURSES		UNITS
ASTE 280	Astronautics and Space Environment I	3
ASTE 301a	Thermal and Statistical Systems I	3
ASTE 330	Astronautics and Space Environment II	3
ASTE 420	Spacecraft Design	3
ASTE 470	Spacecraft Propulsion	3
ASTE 480	Spacecraft Dynamics	3
Total:		minimum 18

Master of Science in Astronautical Engineering

This degree is in the highly dynamic and technologically advanced area of astronautics and space technology. The program is designed for those with B.S. degrees in science and engineering who wish to work in the space sector of the aerospace industry, government research and development centers and laboratories, and academia. In some cases the applicant may be required to take 1-2 upper-division undergraduate classes (which can be credited toward the M.S. degree) to make up the deficiency. The program is available through the USC Distance Education Network (DEN).

The general portion of the Graduate Record Examinations (GRE) and two letters of recommendation are required.

Required courses: 27 units

CORE REQUIREMENT (6 UNITS)		UNITS
ASTE 520	Spacecraft System Design	3
ASTE 535	Space Environments and Spacecraft Interactions	3

CORE ELECTIVE REQUIREMENT (CHOOSE ONE)		UNITS
ASTE 470	Spacecraft Propulsion	3
ASTE 523	Design of Low Cost Space Missions	3
ASTE 552	Spacecraft Thermal Control	3
ASTE 553	Systems for Remote Sensing from Space	3
ASTE 556	Spacecraft Structural Dynamics	3
ASTE 580	Orbital Mechanics I	3
ASTE 583	Space Navigation: Principles and Practice	3
ASTE 584	Spacecraft Power Systems	3
ASTE 585	Spacecraft Attitude Control	3
ASTE 586	Spacecraft Attitude Dynamics	3

RECOMMENDED TECHNICAL ELECTIVES		UNITS
ASTE 501ab	Physical Gas Dynamics	3-3
ASTE 527	Space Studio Architecting	3
ASTE 541	Partially Ionized Plasmas	3
ASTE 545	Computational Techniques in Rarefied Gas Dynamics	3
ASTE 572	Advanced Spacecraft Propulsion	3
ASTE 581	Orbital Mechanics II	3
ASTE 599	Special Topics	3
SAE 549	Systems Architecting I	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 or from the list of recommended technical electives above. No more than 3 units of directed research (ASTE 590) can be applied to the 27-unit requirement. New courses on emerging space technologies are often offered; consult the current semester's course offerings, particularly for ASTE 599 Special Topics.

ENGINEERING MATHEMATICS REQUIREMENT (6 UNITS)		UNITS
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3

At least 21 units must be at the 500 or 600 level.

Engineer in Astronautical Engineering

The Engineer degree in Astronautical Engineering is in the highly dynamic and technologically advanced area of space technology. The program is designed for those with Master of Science degrees in science and engineering who want to prepare for work in the space industry, government research and development centers, and national laboratories. The applicant may be required to take 1-2 upper division undergraduate courses. The Engineer degree in Astronautical Engineering is awarded in strict

conformity with the general requirements for the USC Graduate School. See the general requirements for graduate degrees on page 520. Each student wishing to undertake the Engineer program must first be admitted to the program and then take the screening examination. Further guidance concerning admission, screening exam and the full completion of courses, including those given outside the Astronautics and Space Technology Division, can be obtained from the ASTD student advisor, program coordinators and faculty in each technical area.

Doctor of Philosophy in Astronautical Engineering

The Ph.D. in Astronautical Engineering is awarded in strict conformity with the general requirements of the USC Graduate School. See general requirements for graduate degrees on page 81. The degree requires a concentrated program of study, 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 the graduate course work. Further guidance concerning admission, the screening exam and the full completion of courses, including those given outside the Astronautics and Space Technology Division, can be obtained from the ASTD student advisor and program coordinators.

Certificate in Aerospace Engineering (Astronautics)

The Certificate in Astronautical Engineering is designed for practicing engineers and scientists who enter space-related fields and/or want to obtain training in specific space-related areas. Students enroll at USC as limited status students; they must apply and be admitted to the certificate program after completion of no more than 9 units of required course work. The required course work consists of 12 units; students will choose four 3-unit courses from the following:

REQUIRED COURSES (CHOOSE FOUR)		UNITS
ASTE 501ab	Physical Gas Dynamics	3-3
ASTE 520	Spacecraft System Design	3
ASTE 523	Design of Low Cost Space Missions	3
ASTE 527	Space Studio Architecting	3
ASTE 535	Space Environments and Spacecraft Interactions	3
ASTE 552	Spacecraft Thermal Control	3
ASTE 553	Systems for Remote Sensing from Space	3
ASTE 556	Spacecraft Structural Dynamics	3

ASTE 572	Advanced Spacecraft	
	Propulsion	3
ASTE 580	Orbital Mechanics I	3
ASTE 581	Oribital Mechanics II	3
ASTE 583	Space Navigation:	
	Principles and Practice	3
ASTE 584	Spacecraft Power Systems	3
ASTE 585	Spacecraft Attitude Control	3
ASTE 586	Spacecraft Attitude	
	Dynamics	3
ASTE 599	Special Topics	3

Most classes are available through the USC Distance Education Network (DEN).

Credit for classes may be applied toward the M.S., Engineer or Ph.D. in Astronautical 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.

Courses of Instruction

ASTRONAUTICS AND SPACE TECHNOLOGY (ASTE)

101L Introduction to Astronautics (4, Fa) Gateway to the Astronautical Engineering major. Introduction to space, space exploration and the space business. Elements of orbits, spacecraft systems, rocket propulsion, and communications. Laboratory: introduction to graphics, computation and simulation.

280 Astronautics and Space Environment I (3, Sp) 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. (Duplicates credit in former AME 282.) *Prerequisite:* MATH 226, PHYS 152*L*.

301ab Thermal and Statistical Systems (3-3, FaSp) Thermodynamics and statistical mechanics; kinetics of atoms, molecules, and photons; compressible fluid dynamics. (Duplicates credit in former AME 311*ab*.) *Prerequisite:* MATH 245, PHYS 153*L*.

330 Astronautics and Space Environment II (3, Fa) 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. (Duplicates credit in former AME 382.) *Prerequisite:* ASTE 280, PHYS 153*L*.

420 Spacecraft Design (3, Fa) Spacecraft mission design, space environment, attitude determination and control, telecommunications, propulsion, structures and mechanisms, thermal control, power systems, launch systems and facilities. (Duplicates credit in former AME 482.) *Prerequisite:* junior or senior standing in engineering or physics.

445 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. (Duplicates credit in former AME 485.) *Recommended preparation:* AME 309 or ASTE 301*b*.

470 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. (Duplicates credit in former AME 473.) *Prerequisite:* senior or graduate standing.

480 Spacecraft Dynamics (3) Two-body motion, rigid-body motion, attitude dynamics and maneuvers, spacecraft stabilization: gravity gradient, reaction wheels, magnetic torques, thruster attitude control. (Duplicates credit in former AME 483.) *Prerequisite*: senior standing.

499 Special Topics (2-4, max 8) Course content to be selected each semester from current developments in astronautics, space technology, and related fields.

501ab 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. (Duplicates credit in former AME 520*ab*.) *Prerequisite:* ASTE 501*a*.

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

523 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. (Duplicates credit in former AME 506.) Graduate standing in engineering or science. *Recommended preparation:* ASTE 520 or some experience in space engineering.

527 Space Studio Architecting (3, Sp) Programmatic/conceptual design synthesis/choice creation methods for complex space missions. Aerospace system engineering/Architecture tools to create innovative projects. Evaluated by faculty/industry/NASA experts. Graduate standing in engineering or science. (Duplicates credit in former AME 557). *Recommended preparation:* ASTE 520 or experience in space industry.

535 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. (Duplicates credit in former AME 585.)

541 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. (Duplicates credit in former AME 586.)

545 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. (Duplicates credit in former AME 564.) *Recommended preparation:* ASTE 501*a* and skill in FORTRAN programming.

552 Spacecraft Thermal Control (3, Sp) Spacecraft and orbit thermal environments; design, analysis, testing of spacecraft thermal control system and components; active and passive thermal control, spacecraft and launch vehicle interfaces. Graduate standing in engineering or science.

553 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. (Duplicates credit in former AME 502.) Graduate standing in engineering or physics.

556 Spacecraft Structural Dynamics (3) Applied analytical methods (vibrations of single and multi-degree of freedom systems, finite element modeling, spacecraft applications); requirements definition process; analytical cycles; and design verification. Graduate standing in engineering or science.

572 Advanced Spacecraft Propulsion (3, Sp) Nuclear, electric, sails, and far-term propulsion systems. Overviews of nozzles, heat transfer, electromagnetics, rarefied gases, and plasma physics. Analysis of electrothermal, electrostatic and electromagnetic thrusters. Graduate standing in engineering or science. (Duplicates credit in former AME 573.) *Recommended preparation:* ASTE 470.

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. (Duplicates credit in former AME 580.)

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

583 Space Navigation: Principles and Practice (3, Sp) Statistical orbit determination: (weighted) least squares, batch and sequential (Kalman) processing, illustrative examples; online ephemeris generation: potentially hazardous asteroids, comets, satellites; launch: vehicles, payloads, staging. Graduate standing in engineering or science. (Duplicates credit in former AME 558.) *Recommended preparation:* ASTE 580.

584 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. (Duplicates credit in former AME 508.)

585 Spacecraft Attitude Control (3, SpSm) Review of attitude dynamics, gravity gradient stabilization, attitude stabilization with a spin, attitude maneuvers, control using momentum exchange devices, momentum-biased stabilization, reaction thruster control. (Duplicates credit in former AME 582.) *Prerequisite:* AME 451 or EE 482; *recommended preparation:* a course in dynamics.

586 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. (Duplicates credit in former AME 583.)

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 division. Graded CR/NC.

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

599 Special Topics (2-4, max 9) Course content to be selected each semester from current developments in astronautics, space technology, and related fields.

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

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

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

Biomedical Engineering

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Chair: Michael C. K. Khoo, Ph.D.

Faculty
Dwight C. and Hildagarde E. Baum Chair in Biomedical Engineering: Michael C.K. Khoo, Ph.D.

David Packard Chair in Engineering: Theodore W. Berger, 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);* Roberta D. Brinton, Ph.D. *(Molecular Pharmacology and Toxicology);* David Z.

D'Argenio, Ph.D.*; Norberto M. Grzywacz, Ph.D.; H. K. Huang, D.Sc. *(Radiology);* Mark S. Humayun, Ph.D. *(Ophthalmology);* 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.; Anupam Madhukar, Ph.D. *(Materials Science and Physics);* 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);* K. Kirk Shung, Ph.D.; Manbir Singh, Ph.D. *(Radiology);* Armand R. Tanguay, Jr., Ph.D. *(Electrical Engineering, Materials Science);* Ivan Vesely, Ph.D. (*Cardiothoracic Surgery*)*;* Stanley M. Yamashiro, Ph.D. *(Electrical Engineering)*

Associate Professors: Peter S. Conti, M.D., Ph.D. *(Radiology);* Daniel P. Holschneider, M.D. *(Psychiatry);* Sandra Howell, Ph.D. *(Biokinesiology and Physical Therapy);* Kwang-Jin Kim, Ph.D. *(Medicine and Physiology);* Zhong-Lin Lu, Ph.D. *(Psychology);* Jill McNitt-Gray, Ph.D. *(Exercise Science);* Bartlett W. Mel, Ph.D.

Assistant Professors: Tzung K. Hsiai, M.D., Ph.D. *(Cardiovascular Medicine);* Hossein Jadvar, M.D., Ph.D. *(Radiology);* Ellis F.

Meng, Ph.D.; James D. Weiland, Ph.D. *(Ophthalmology);* Jesse T. Yen, Ph.D.

Research Professors: Gilbert A. Chauvet, Ph.D., M.D. *(Theoretical Biology, University of Angers, France);* Alfred E. Mann, M.S. *(AMI-USC);* Donald J. Marsh, M.D.; Robert V. Shannon, Ph.D. *(House Ear Institute);* Peter Staudhammer, Ph.D. (*AMI-USC*)

Research Associate Professor: Laura Marcu, Ph.D. *(Electrical Engineering — Electrophysics)*

Research Assistant Professors: Jonathan M. Cannata, Ph.D.; Rahman Davoodi, Ph.D.; Qian-Jie Fu, Ph.D. *(House Ear Institute);* Ghassan Gholmieh, M.D., Ph.D.; John J. Granacki, Ph.D. *(Electrical Engineering-Systems/ISI);* David K. Merwine, Ph.D.; Ramez E.N. Shehada, Ph.D.; Wee Ling Wong, Ph.D.; Xiaping Xie, M.D.; Walter M. Yamada, Ph.D.; Qifa Zhou, Ph.D.

Assistant Professors of Research: Fei Cao, Ph.D. *(Radiology);* Stephan G. Erberich, Ph.D. *(Radiology);* Thomas P. Hedman, Ph.D. *(Orthopedics);* Brent J. Liu, Ph.D. *(Radiology);* Greg T. Mogel, M.D. *(Radiology);* John C. Wood, Ph.D. *(Pediatric Cardiology, Childrens Hospital);* Tishya A.L. Wren, M.D., Ph.D. *(Orthopedics/Pediatrics Childrens Hospital and Radiology)*

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

Adjunct Associate Professor: Samuel E. Landsberger, Sc.D. *(Rancho Los Amigos Medical Center)*

Senior Lecturer: Jean-Michel I. Maarek, Doc.Ing.

*Recipient of university-wide or school teaching award.

Degree Requirements

Educational Program Objectives
The educational program objectives of the Department of Biomedical Engineering at the University of Southern California are designed to promote technical competence, professionalism and citizenship.

Technical Competence
Graduates will have fundamental knowledge in science and engineering and the ability to apply engineering principles to define and solve problems in engineering and medicine.

Graduates will have the ability to design and test devices, components, processes and systems that meet desired needs in biomedical engineering.

Professionalism
Graduates will be prepared professionally and personally to practice engineering in biomedical and other technology-based industries, as well as to succeed in medical school and advanced graduate studies.

Graduates will have the leadership capabilities and communication skills to succeed in multidisciplinary teams.

Graduates will understand that their professional responsibility includes continued development of their knowledge and skills throughout their careers.

Citizenship
Graduates will understand the societal consequences of engineering decisions and will be committed to an ethical and socially responsible professional practice.

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 518.

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
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
BISC 120L**	General Biology: Organismal Biology and Evolution	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 220L	General Biology: Cell Biology and Physiology	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
BME 423	Statistical Methods in Biomedical Engineering	3
CHEM 322aL	Organic Chemistry	4
EE 202L	Linear Circuits	4
WRIT 340	Advanced Writing	3
Elective	Technical	3
		17

THIRD YEAR, SECOND SEMESTER		**UNITS**
BME 302L	Medical Electronics	4
CHEM 322bL	Organic Chemistry	4
EE 301	Introduction to Linear Systems	3
Elective	Technical	3
General education		4
	18

FOURTH YEAR, FIRST SEMESTER		**UNITS**
BISC 320L	Molecular Biology	4
BME 403	Physiological Systems	3
BME 410	Introduction to Biomaterials and Tissue Engineering	3
General education		4
	14

FOURTH YEAR, SECOND SEMESTER		**UNITS**
BME 402	Control and Communication in the Nervous System	3
BME 405L	Senior Projects: Measurements and Instrumentation	4
BME 414	Rehabilitation Engineering	3
Elective	Technical	4
General education		4
	18

*Taken concurrently.

**Satisfies general education Category III.

Accelerated Dual Degree Program: Bachelor of Science/Master of Science in Biomedical Engineering

The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to six units of course work will be counted toward satisfying the unit requirements of both programs. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

Bachelor of Science in Biomedical Engineering (Biochemical Engineering)

The requirement for the degree is 132 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 518.

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 120L**	General Biology: Organismal Biology and Evolution	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 220L	General Biology: Cell Biology and Physiology	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 320L	Molecular Biology	4
BME 423	Statistical Methods in Biomedical Engineering	3
CHE 330	Chemical Engineering Thermodynamics	4
CHEM 322aL	Organic Chemistry	4
MASC 310	Materials Behavior and Processing	3
	18

THIRD YEAR, SECOND SEMESTER		**UNITS**
BISC 330L	Biochemistry	4
CHE 350	Introduction to Separation Processes	3
CHEM 322bL	Organic Chemistry	4
WRIT 340	Advanced Writing	3
General education		4
	18

FOURTH YEAR, FIRST SEMESTER		**UNITS**
BME 403	Physiological Systems	3
BME 410	Introduction to Biomaterials and Tissue Engineering	3
BME 416	Development and Regulation of Medical Products	3
EE 202L	Linear Circuits	4
General education		4
	17

FOURTH YEAR, SECOND SEMESTER		**UNITS**
BME 402	Control and Communication in the Nervous System	3
BME 405L	Senior Projects: Measurements and Instrumentation	4
CHE 460L	Chemical Process Dynamics and Control	4
CHE 489	Biochemical Engineering	3
General education		4
	18

*Taken concurrently.

**Satisfies general education Category III.

Bachelor of Science in Biomedical Engineering (Electrical Engineering)

The requirement for the degree is 133 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 518.

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
EE 201L	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

BME 423	Statistical Methods in Biomedical Engineering	3
CHEM 322aL	Organic Chemistry	4
EE 301	Introduction to Linear Systems	3
BME 403	Physiological Systems	3
General education		4
		17

THIRD YEAR, SECOND SEMESTER — UNITS

BISC 220L	General Biology: Cell Biology and Physiology	4
EE 338	Physical Electronics	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

BISC 320L	Molecular Biology	4
BME 405L	Senior Projects: Measurements and Instrumentation	4
BME 425	Basics of Biomedical Imaging	3
EE 348L	Electronic Circuits I	4
		15

FOURTH YEAR, SECOND SEMESTER — UNITS

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
Elective	Technical	3
		17

*Taken concurrently.

**Satisfies general education Category III.

Bachelor of Science in Biomedical Engineering (Mechanical Engineering)
The requirement for the degree is 132 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.

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 201	Statics	3
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
		15

SECOND YEAR, SECOND SEMESTER — UNITS

AME 204	Strength of Materials	3
BISC 220L	General Biology: Cell Biology and Physiology	4
BME 210	Biomedical Computer Simulation Methods	3
MATH 245	Mathematics of Physics and Engineering I	4
General education		4
		18

THIRD YEAR, FIRST SEMESTER — UNITS

AME 301	Dynamics	3
AME 309	Dynamics of Fluids	4
CHEM 322aL	Organic Chemistry	4
MASC 310	Materials Behavior and Processing	3
General education		4
		18

THIRD YEAR, SECOND SEMESTER — UNITS

AME 302	Design of Dynamic Systems	3
EE 202L	Linear Circuits	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
General Education		4
Elective	Technical	3
		18

FOURTH YEAR, FIRST SEMESTER — UNITS

BISC 320L	Molecular Biology	4
BME 403	Physiological Systems	3
BME 404	Biomechanics	3

BME 405L	Senior Projects: Measurements and Instrumentation	4
BME 423	Statistical Methods in Biomedical Engineering	3
		17

FOURTH YEAR, SECOND SEMESTER		UNITS
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
BME 402	Control and Communication in the Nervous System	3
General education		4
Elective	Technical	3
Writing 340	Advanced Writing	3
		16

*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 Viterbi 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. Four of these units may 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 511	Physiological Control Systems	3
BME 513*	Signal and Systems Analysis	3
BME 533	Seminar in Bioengineering	1
BME 594abz	Master's Thesis (2-2-0), or Technical Elective (4)	4
Electives	Technical	9
		28

*Students who have taken an advanced undergraduate or master's level course in system and signal analysis may substitute BME 523 for BME 513.

Master of Science in Biomedical Engineering (Medical Imaging and Imaging Informatics)

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 (Medical Imaging and Imaging Informatics) 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 501	Advanced Topics in Biomedical Systems	4
BME 513	Signal and Systems Analysis	3
BME 525	Advanced Biomedical Imaging	4
BME 527	Integration of Medical Imaging Systems	3
BME 528	Medical Imaging Informatics	3
BME 535	Ultrasonic Imaging	3
EE 569	Introduction to Digital Image Processing	3
Electives	Technical	6
		29

Master of Science in Medical Device and Diagnostic Engineering

This program is designed to provide the knowledge and skills needed for the development of medical devices and diagnostic techniques, including aspects of medical product regulation. The course of study requires successful completion of 31 units of course work and has been designed to be completed in three semesters of full-time study.

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 620L	Applied Electrophysiology	4
BME 650	Biomedical Measurement and Instrumentation	3
MPTX 511	Introduction to Medical Product Regulation, or	
BME 416	Development and Regulation of Medical Products	3
MPTX 513	Regulation of Medical Devices and Diagnostics	3
MPTX 515	Quality Systems and Standards, or	
ISE 527	Quality Management for Engineers	3
Elective		4
		31

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, biochemistry, 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 that 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.

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. *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.

350 Biomedical Engineering Industrial Project (3) Training in specific skills relevant to biomedical industry. Placement in summer internship following successful completion of the course. Junior standing. *Prerequisite:* BME 210.

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 220*L*, BME 210, 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 220*L*; MATH 245; *corequisite:* EE 202*L*.

404 Biomechanics (3, Fa) Mechanical properties of biological tissues and fluid transport in physiological systems: blood rheology; bioviscoelastic solids and fluids; gas flow and mixing; prosthesis design. *Prerequisite:* PHYS 151*L;* MATH 245; AME 201.

405L Senior Projects: Measurements and Instrumentation (4, FaSp) 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) Software projects employing engineering, mathematical, and computational principles; applications include sensory and motor processing. *Prerequisite:* BME 210.

410 Introduction to Biomaterials and Tissue Engineering (3, Fa) Application of principles of physical chemistry, biochemistry, and materials engineering to biomedical problems, e.g., materials selection and design for implants and tissue replacement. *Prerequisite:* CHEM 322*aL*.

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

416 Development and Regulation of Medical Products (3, Sp) An introduction to the process of medical product development with emphasis on the regulations that govern the design, fabrication, and maintenance of medical products. Junior standing. Departmental approval required.

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. *Prerequisite:* BME 210.

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*.

451 Fundamentals of Biomedical Microdevices (3, Fa) Introduction to biomedical microdevices with emphasis on microtechnologies and biomedical microelectromechanical systems (bioMEMS). Principles for measurement of small-scale biological phenomena and clinical applications. *Prerequisite:* EE 202L; *recommended preparation:* basic biology and electronics.

452 Introduction to Biomimetic Neural Engineering (3, Fa) Engineering principles, biology, technological challenges and state-of-the-art developments in the design of implantable biomimetic microelectronic devices that interface with the nervous system. *Prerequisite:* EE 202; *recommended preparation:* basic biology and electronics.

480 Senior Design for Biomedical Engineers (3) Engineering design principles applied to biomedical systems; design and implementation of a biomedical hardware and software project; presentation and demonstration. *Prerequisite:* BME 405*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, Fa) Advanced topics in selected biomedical systems: cardiopulmonary, neuromuscular, renal and endocrine.

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.

511 Physiological Control Systems (3, Sp) Application of control theory to physiological systems; static analysis of closed-loop systems; time-domain analysis of linear control identification methods; nonlinear control.

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, Fa) 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 Integration of Medical Imaging Systems (3, Fa) Medical imaging quality, compression, data standards, workflow analysis and protocols, broadband networks, image security, fault tolerance, picture archive communication system (PACS), image database and backup.

528 Medical Imaging Informatics (3, Sp) Picture archive communication system (PACS) design and implementation; clinical PACS-based imaging informatics; telemedicine/teleradiology; image content indexing, image data mining; grid computing in large-scale imaging informatics; image-assisted diagnosis, surgery and therapy. *Prerequisite:* BME 425 or BME 525, BME 527.

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

535 Ultrasonic Imaging (3, Sp) All aspects of ultrasonic imaging including ultrasound and tissue interaction, ultrasonic transducers, instrumentation, imaging methods, clinical applications, bioeffects, safety, and recent developments in the field.

551 Introduction to Bio-MEMS and Nanotechnology (3, Fa) Principles and biomedical applications of micro-electromechanical systems (MEMS) and nanotechnology, including microfluidics, nanowire sensors, nanomotors, quantum dots, biofuel cells and molecular imaging. *Recommended preparation:* Basic biology and electronics.

552 Neural Implant Engineering (3, Sp) Advanced studies of the basic neuroscience, engineering design requirements and technological issues associated with implantable neural prostheses, with particular emphasis on retinal and cortical function.

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) 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.

620L Applied Electrophysiology (4, Fa) The theoretical basis and applied design principles for medical devices and instrumentation that interact with electrically excitable tissues of the body. *Prerequisite:* BME 502.

650 Biomedical Measurement and Instrumentation (3, Sp) Design of measurement systems and biomedical instrumentation; architecture of electronic instruments used to measure physiological parameters, analysis of major process functions integrated in these instruments. Open to M.S., Medical Device and Diagnostic Engineering and biomedical engineering Ph.D. students only. *Prerequisite:* BME 513.

670 Early Visual Processing (4, Fa) Interdisciplinary topics in biological and artificial low-level visual processing. Retina, lateral geniculate nucleus; computer vision; neurophysiology; retinal prosthesis; molecular biology, phototransduction; edge detection; movement. Open to graduate students only. *Prerequisite:* NEUR 524 and NEUR 525; or BME 502; or CSCI 574.

671 Late Visual Processing (4, Sp) Interdisciplinary topics in biological and artificial high-level visual processing. Visual cortex; computer vision; neurophysiology; psychophysics; MRI; computational models; orientation selectivity; steropsis; motion; contours; object recognition. Open to graduate students only. *Prerequisite:* NEUR 524 and NEUR 525; or BME 502; or CSCI 574.

675 Computational Vision (3, Fa) Biological vision; natural statistics; enzymatic cascades; predictive coding; dendrites and active conductances; system identification; energy models; population code; Kalman filtering; Bayesian models; regularization; object recognition. *Prerequisite:* BME 502.

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

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

Associate Professors: Wenji Victor Chang, Ph.D.; Ching-An Peng, Ph.D.; Katherine S. Shing, Ph.D.*

Assistant Professors: C. Ted Lee, Ph.D.; Pin Wang, Ph.D.

Adjunct Assistant Professors: Michael Kezirian, Ph.D.; Ian Webster, Sc.D.

Emeritus Professors: Elmer L. Dougherty, Ph.D. *(Petroleum Engineering);* Ronald Salovey, Ph.D.*

*Recipient of university-wide or school teaching award.

Chemical Engineering Honor Society: Omega Chi Epsilon

Degree Requirements

Educational Program Objectives
Chemical Engineering is the engineering discipline which makes extensive use of chemical transformations (i.e., reactions) in addition to physical transformations (such as machining and molding) to achieve added value. Because all manufacturing involves chemical transformations in one way or another, chemical engineers are employed in virtually all manufacturing industries, from the basic chemical, materials, energy, food, pharmaceutical and microelectronics industries to the myriad consumer product industries. This means that chemical engineers must be very broadly educated and trained as well as highly adaptable.

To ensure that our graduates are adequately prepared for graduate studies in basic chemical engineering, as well as various related fields (such as 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 objectives:

(1) To provide each student with a rigorous 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 them 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.

(5) To develop in the students an understanding of professional and ethical responsibilities towards the individual, society and the environment; as well as an appreciation of societal, historical and global issues.

Bachelor of Science in Chemical Engineering Degrees
The Department of Chemical Engineering offers five Bachelor of Science degrees: B.S., Chemical Engineering (132 units); B.S., Chemical Engineering (Biochemical Engineering) (136 units); B.S., Chemical Engineering (Environmental Engineering) (135 units); B.S., Chemical Engineering (Petroleum Engineering) (136 units); and B.S., Chemical Engineering (Polymer Science) (136 units).

Sample student schedules are located on the department Web page *(www.usc.edu/dept/che).*

Common Requirements for all Bachelor of Science Degrees (111 units)
See also common requirements for undergraduate degrees section, page 518.

GENERAL EDUCATION COURSES***		UNITS
PHYS 151 satisfies Category III		20

WRITING COURSES		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

CHEMISTRY COURSES		UNITS
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
CHEM 300L	Analytical Chemistry	4
CHEM 322aL	Organic Chemistry	4
CHEM 430a	Physical Chemistry	4

MATH COURSES		UNITS
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4

PHYSICS COURSES		UNITS
PHYS 151**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152	Fundamentals of Physics II: Electricity and Magnetism	4

CHEMICAL ENGINEERING COURSES		UNITS
CHE 120	Introduction to Chemical Engineering	3
CHE 330	Chemical Engineering Thermodynamics	4
CHE 350	Introduction to Separation Processes	3
CHE 442	Chemical Reactor Analysis	4
CHE 443	Viscous Flow	3
CHE 444abL	Chemical Engineering Laboratory	3-3
CHE 445	Heat Transfer in Chemical Engineering Processes	2
CHE 446	Mass Transfer in Chemical Engineering Processes	2
CHE 460L	Chemical Process Dynamics and Control	4
CHE 480	Chemical Process and Plant Design	3

OTHER COURSES		UNITS
CSCI 101L	Fundamentals of Computer Programming	3
ISE 460	Engineering Economy, or	
BUAD 301	Technical Entrepreneurship	3

* Taken concurrently with GE Category VI course.
** Satisfies General Education Category III.
*** Diversity course must double count as a general education course in calculating the total unit count for the degree.

Additional Requirements for Individual Degrees

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. In addition to the previously listed common requirements, students must also take the following courses:

CHEMISTRY TECHNICAL ELECTIVE		UNITS
CHEM 322bL	Organic Chemistry, or	
CHEM 430b	Physical Chemistry	4

CHEMICAL ENGINEERING COURSES		UNITS
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 476	Chemical Engineering Materials	3
CHE 485	Computer-Aided Chemical Process Design	3
CHE Technical Elective		
An upper division CHE course		3

OTHER ENGINEERING COURSES		UNITS
CE 205	Statics	2
EE 438L	Processing for Microelectronics	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 Department of Chemical Engineering, Biomedical Engineering and Biological Sciences. In addition to the previously listed common requirements, students must also take the following courses:

BIOLOGICAL SCIENCES COURSES		UNITS
BISC 300L	Introduction to Microbiology	4
BISC 320L	Molecular Biology	4
BISC 330L	Biochemistry	4
BISC 403	Advanced Molecular Biology	4

CHEMICAL ENGINEERING COURSES		UNITS
BME 410	Introduction to Biomaterials and Tissue Engineering	3
CHE 489	Biochemical Engineering	3
CHE Technical Elective		
CHE 405	Applications of Probability and Statistics for Chemical Engineers, or	
CHE 485	Computer-Aided Chemical Process Design	3

Bachelor of Science in Chemical Engineering (Environmental Engineering)
The requirement for the degree is 135 units. A scholarship 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. In addition to the previously listed common requirements, students must also take the following courses:

CHEMICAL ENGINEERING COURSES		UNITS
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 476	Chemical Engineering Materials	3
CHE 485	Computer-Aided Chemical Process Design	3
CHE 486	Design of Environmentally Benign Process Plants	3

OTHER COURSES		UNITS
CE 453	Water Quality Control	3
CE 463L	Water Chemistry and Analysis	3
PTE 463L	Introduction to Transport Processes in Porous Media	3
Air Pollution Elective		
ENE 428	Air Pollution Fundamentals, or	
ENE 429	Air Pollution Control	3

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 and in the Department of Petroleum Engineering. In addition to the previously listed common requirements, students must also take the following courses:

CHEMISTRY COURSE		UNITS
Chemistry Technical Elective		
CHEM 322bL	Organic Chemistry, or	
CHEM 430b	Physical Chemistry	4

CHEMICAL ENGINEERING COURSES		UNITS
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 476	Chemical Engineering Materials	3
CHE 485	Computer-Aided Chemical Process Design	3

OTHER ENGINEERING COURSES		UNITS
PTE 461	Formation Evaluation	3
PTE 463L	Introduction to Transport Processes in Porous Media	3
PTE 464L	Petroleum Reservoir Engineering	3
PTE 465L	Drilling Technology and Subsurface Methods	3

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 Department of Chemical Engineering, Biomedical Engineering, Materials Science and Electrical Engineering. In addition to the previously listed common requirements, students must also take the following courses.

CHEMISTRY COURSES		UNITS
Chemistry Technical Elective		
CHEM 322bL	Organic Chemistry, or	
CHEM 430b	Physical Chemistry	4

CHEMICAL ENGINEERING COURSES		UNITS
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 472	Polymer Science and Engineering	3
CHE 474L	Polymer Science and Engineering Laboratory	3
CHE 476	Chemical Engineering Materials	3

| CHE 477 | Computer Assisted Polymer Engineering and Manufacturing | 3 |
| CHE 485 | Computer-Aided Chemical Process Design | 3 |

OTHER ENGINEERING COURSES		UNITS

Materials Elective

BME 410	Introduction to Biomaterials and Tissue Engineering, or	
CHE 475	Physical Properties of Polymers, or	
EE 438L	Processing for Microelectronics	3

Accelerated Dual Degree Program: Bachelor of Science/Master of Science in Chemical Engineering
The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to six units of course work will be counted toward satisfying the unit requirements of both programs. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

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 Viterbi School of Engineering with the exception that the minimum unit requirement is 28. Registration in CHE 550ab is 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. Registration in CHE 550ab is 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 (3, 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:* CHEM 105*bL* or CHEM 115*bL*; *recommended preparation:* CHE 330.

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 and Tissue Engineering (3, Fa) (Enroll in BME 410)

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

443 Viscous Flow (3, Sp) Constitutive equations and rate laws, momentum equations and kinetic theory of Newtonian, Non-Newtonian and complex flows. Applications to chemical engineering systems. *Corequisite:* CHE 350, MATH 245.

444abL Chemical Engineering Laboratory (3-3, FaSp) Resolution of chemical engineering problems that require original planning, observations, and data interpretation. Written and oral reports. *Prerequisite:* CHE 330, CHE 350, CHE 442; *corequisite:* CHE 443.

445 Heat Transfer in Chemical Engineering Processes (2, Fa) Phenomenological rate laws, differential and macroscopic equations, and elementary kinetic theory of heat transfer processes, with emphases on conduction and convection. (Duplicates credit in AME 331.) *Prerequisite:* CHE 443, MATH 245.

446 Mass Transfer in Chemical Engineering Processes (2, Sp) Molecular and continuum approaches to diffusion and convection in fluids and multicomponent mixtures; simultaneous mass, heat and momentum transfer; steady-state and time-dependent diffusion; Maxwell-Stefan equations. *Prerequisite:* MATH 245, CHE 443, CHE 445.

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,Sp) 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 semicrystalline 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, Sp) 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.

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, Sp) 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 320*L* 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, Fa) Application of mathematics to problems in chemical engineering; mathematical modeling, differential and integral equations, linear systems analysis and stability, asymptotic and numerical methods. Graduate Standing.

502 Numerical Methods for Diffusive and Convective Transport (3, Sm) Numerical solution of ordinary and partial differential equations describing fluid flow, diffusion with chemical reaction, and conduction in heterogeneous media. Graduate standing.

513 Principles of Combustion (3) (Enroll in AME 513)

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

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

530 Thermodynamics for Chemical Engineers (3, Sp) 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 AME 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, Sp) 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.

550ab Seminars in Chemical Engineering (0-1, max 2, FaSp) Seminars to cover recent developments in the field of chemical engineering given by invited speakers. Master's students must register for two semesters; Ph.D. students must register for four semesters. Graded IP/CR/NC. *Recommended preparation:* graduate standing.

554 Principles of Tissue Engineering (3, Fa) Advanced scientific and engineering principles of tissue engineering including stem cell biology, biomaterial scaffolds, protein-surface interaction, bioreactor, and selected bioartificial organs (e.g., kidney, bone, skin). *Recommended preparation:* CHE 476, CHE 489.

560 Advanced Separation and Bioseparation Processes (3, Sp) Experimental techniques for separation and bioseparation processes and theoretical and computational techniques for modeling them. Graduate standing.

572 Advanced Topics in Polymer Kinetics and Rheology (3, Fa) Kinetics of polymer synthesis reactions and rheology of polymer solutions. *Recommended preparation:* CHE 442, CHE 472.

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
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);* Roger Ghanem, Ph.D.; Peter Gordon, Ph.D. *(Policy, Planning, and Development; Economics);* Genevieve Giuliano, Ph.D. *(Policy, Planning, and Development);* Ronald C. Henry, Ph.D. *(Environmental Engineering);* Jiin-Jen Lee, Ph.D., P.E. *(Environmental Engineering)*;* Vincent W. Lee, Ph.D.; Geoffrey R. Martin, Ph.D.; Sami F. Masri, Ph.D. *(Mechanical Engineering);* James Moore, Ph.D. *(Policy, Planning, and Development);* William J. Petak, D.P.A. *(Policy, Planning, and Development);* Massoud Pirbazari, Ph.D. *(Environmental Engineering, Associate Director of Environmental Engineering);* Constantinos Sioutas, Sc.D.; 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: Najmedin Meshkati, Ph.D., C.P.E. *(Industrial and Systems Engineering);* Yan Xiao, Ph.D., P.E.

Assistant Professors: Erik A. Johnson, Ph.D.; Amy L. Rechenmacher, Ph.D.

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

Research Professors: Edward Kavazanjian, Jr., P.E., G.E.; Maria I. Todorovska, Ph.D.; Dennis E. Williams

Research Associate Professors: Robert Nigbor, Ph.D., P.E.; Craig Taylor, Ph.D.

Research Assistant Professors: Jose C. Borrero, Ph.D.; John Caffrey, Ph.D.; Philip M. Fine, Ph.D.; Michael D. Geller, Ph.D.; Le Dam Hanh, Ph.D.; John A. Kuprenas, D.Eng., P.E.; Jennifer N. Swift, Ph.D.

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

Educational Program Objectives

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, or to continue their graduate studies in engineering, or to enter related areas such as 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)

The B.S. in Civil Engineering has three tracks: general, construction and water resources.

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, CE 225, CE 309 and CE 325. See also common requirements for undergraduate degrees section, page 518.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
		7

GENERAL EDUCATION, SEE PAGE 60	UNITS
Category VI – Social Issues*	20

PRE-MAJOR REQUIREMENTS		UNITS
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Other Requirements		
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry, or	
GEOL 305L	Introduction to Engineering Geology, or	
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
		32

MAJOR REQUIREMENTS		UNITS
School of Engineering		
ENGR 102ab	Engineering Freshman Academy	1-1
Civil Engineering		
CE 106	Design and Planning of Civil Engineering Systems	2
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 205	Statics	2
CE 207L	Introduction to Design of Structural Systems	2
CE 225	Mechanics of Deformable Bodies	3

CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 334L	Mechanical Behavior of Materials	3
CE 358	Theory of Structures I	3
CE 402	Computer Methods in Engineering	3
CE 408	Risk Analysis in Civil Engineering	3
CE 451	Water Resources Engineering	3
CE 453	Water Quality Control	3
CE 456	Design of Steel Structures	3
CE 467L	Geotechnical Engineering	4
CE 471	Principles of Transportation Engineering	3
Capstone Courses		
CE 473	Engineering Law, Finance, and Ethics	3
CE 480	Structural System Design, or	
CE 465	Water Supply and Sewage System Design	3
Courses from other Engineering departments		
EE 202L	Linear Circuits, or	
EE 326L	Essentials of Electrical Engineering	4
		60

MAJOR ELECTIVES		UNITS
Elective	Civil Engineering	6
Design Kernel***	Civil Engineering Design Kernel Course	6
Total Units:		131

*Taken concurrently
**Satisfies a general education requirement for Category III
***Design kernel courses must be selected from the following list of design courses: CE 457, CE 465, CE 466, CE 476, CE 478, CE 482, CE 484 and CE 485.

Tracks

In addition to the core courses, students are required to select one of the following tracks: General, Construction or Water Resources.

General Track

Choose one of the following: CE 480 as the capstone course and CE 482 as a required design kernel course; or CE 465 as the capstone course and CE 466 or CE 476 as a required design kernel course.

The civil engineering electives may be chosen freely.

Construction Track
Select CE 480 as the capstone course and CE 482 as a required design kernel course. Replace CE 453 with CE 412. The civil engineering electives must be chosen from the following list: CE 460, CE 461 and CE 462.

Water Resources Track
Select CE 465 as the capstone course and select one of the following as a required design kernel course: CE 466 or CE 476. The civil engineering electives must be selected from the following list: CE 466, CE 476, CE 477 and CE 490.

Bachelor of Science in Civil Engineering (Structural Engineering Emphasis) (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, CE 225, CE 309 and CE 325. See also common requirements for undergraduate degrees section, page 518.

Bachelor of Science, Civil Engineering (Structural Engineering)

COMPOSITION/WRITING REQUIREMENTS		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION	UNITS
Category VI – Social Issues*	20

PRE-MAJOR REQUIREMENTS		UNITS
Chemistry Requirement		
CHEM105aL	General Chemistry, or	
CHEM115aL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Other Requirements		
GEOL 305Lx	Introduction to Engineering Geology	4
		32

MAJOR REQUIREMENTS		UNITS
School of Engineering courses		
ENGR 102ab	Engineering Freshman Academy	1-1
Civil Engineering courses		
CE 106	Design and Planning of Civil Engineering Systems	2
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 205	Statics	2
CE 207L	Introduction to Design of Structural Systems	2
CE 225	Mechanics of Deformable Bodies	3
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 334L	Mechanical Behavior of Materials	3
CE 358	Theory of Structures I	3
CE 402	Computer Methods in Engineering	3
CE 408	Risk Analysis in Civil Engineering	3
CE 451	Water Resources Engineering	3
CE 456	Design of Steel Structures	3
CE 457	Reinforced Concrete Design	3
CE 458	Theory of Structures II	3
CE 459	Introduction to Structural Dynamics	3
CE 460	Construction Engineering	3
CE 467L	Geotechnical Engineering	4
CE 473	Engineering Law, Finance, and Ethics	3
Capstone course		
CE 480	Structural System Design	3
CE 482	Foundation Design	3
Courses from other engineering departments		
EE 202L	Linear Circuits, or	
EE326L	Essentials of Electrical Engineering	4
		69

MAJOR ELECTIVES		UNITS
Elective***	Civil Engineering	3
Total Units		131

*Taken concurrently.

**Satisfies general education Category III.

***The civil engineering elective must be selected from the following courses: CE 409a, 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 (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, CE 225, CE 309 and CE 325. See also the common requirements for undergraduate degrees section, page 518.

Bachelor of Science, Civil Engineering (Building Science)

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
		7

GENERAL EDUCATION	UNITS
Category VI – Social Issues*	20

PRE-MAJOR REQUIREMENTS		UNITS
Chemistry Requirement		
CHEM105aL	General Chemistry, or	
CHEM115aL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Other Requirements		
GEOL 305Lx	Introduction to Engineering Geology, or	
PHYS 153L	Fundamental of Physics III: Optics and Modern Physics	4
		32

MAJOR REQUIREMENTS		UNITS
Engineering courses		
ENGR 102a	Engineering Freshman Academy	1
Civil Engineering courses		
CE 106	Design and Planning of Civil Engineering Systems	2
CE 107	Introduction to Civil Engineering Graphics	3
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 205	Statics	2
CE 207L	Introduction to Design of Structural Systems	2
CE 225	Mechanics of Deformable Bodies	3
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 334L	Mechanical Behavior of Materials	3
CE 358	Theory of Structures I	3
CE 408	Risk Analysis in Civil Engineering	3
CE 456	Design of Steel Structures	3
CE 457	Reinforced Concrete Design	3
CE 458	Theory of Structures II	3
CE 467L	Geotechnical Engineering	4
Architecture courses		
ARCH 114	Architecture: Culture and Community	2
ARCH 214b	History of Architecture	4
ARCH 205abL***	Building Science I	4-4
ARCH 305abL***	Building Science II	4-4
ARCH 405abL***	Building Science III	4-4
		73

MAJOR ELECTIVES		3 UNITS
Elective****	Civil Engineering	3
Total Units		135

*Taken concurrently.

**Satisfies general education Category III.

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

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

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, CE 225, CE 309 and CE 325. See also common requirements for undergraduate degrees section, page 518.

COMPOSITION/WRITING REQUIREMENT		7 UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
		7

GENERAL EDUCATION, SEE PAGE 60	UNITS
Category VI – Social Issues*	20

PRE-MAJOR REQUIREMENTS		36 UNITS
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
PHYS 153L	Fundamentals of Physics III, or	
GEOL 305xL	Engineering Geology	4
		36

MAJOR REQUIREMENTS		UNITS
School of Engineering		
ENGR 102ab	Engineering Freshman Academy	1-1
CE/ENE Engineering Courses		
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 110	Introduction to Environmental Engineering	3
CE 205	Statics	2
CE 210L	Introduction to Environmental Engineering Microbiology	3
CE 225	Mechanics of Deformable Bodies	3
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 334L	Mechanical Behavior of Materials	3
CE 358	Theory of Structure I	3
CE 408	Risk Analysis in Civil Engineering	3
CE 451	Water Resources Engineering	3
CE 453	Water Quality Control	3
CE 463L	Water Chemistry and Analysis	3
CE 467L	Geotechnical Engineering	4
CE 473	Engineering Law, Finance, and Ethics	3
CE 485	Wastewater Treatment Design	3
ENE 400	Environmental Engineering Principles	3
ENE 428	Air Pollution Fundamentals	3
ENE 429	Air Pollution Control	3
Course from other department		
AME 310	Engineering Thermodynamics I	3
		61

MAJOR ELECTIVE	UNITS
Design Kernel***	6
Total Units:	130

*Taken concurrently

**Satisfies general education Category III requirement

***Kernels must be selected from the following list of design courses: CE 465, CE 466, CE 476, CE 482, CE 484, ENE 486.

Bachelor of Science in Environmental Engineering (132-134 Unit Program)

The degree has two tracks: Track 1: Environmental Systems and Processes (132 units); Track II: Environmental Biotechnology (134 units). 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 and ENE 410. See also common requirements for undergraduate degrees section, page 518.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
		7

GENERAL EDUCATION	UNITS
Category VI – Social Issues*	20

PRE-MAJOR REQUIREMENTS (BOTH TRACKS)		UNITS
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
CHEM 322aL	Organic Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		36

PRE-MAJOR REQUIREMENTS (TRACK II ONLY)		UNITS
Chemistry Requirement		
CHEM 322bL	Organic Chemistry	4

MAJOR REQUIREMENTS (BOTH TRACKS)		UNITS
School of Engineering		
ENGR 102ab	Engineering Freshman Academy	1-1

CE/ENE Engineering Courses

CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 110	Introduction to Environmental Engineering.	3
CE 205	Statics	2
CE 210L	Introduction to Environmental Engineering Microbiology	3
CE 408	Risk Analysis in Civil Engineering	3
CE 451	Water Resources Engineering	3
CE 453	Water Quality Control	3
CE 463L	Water Chemistry and Analysis	3
CE 465	Water Supply and Sewage System Design	3
CE 473	Engineering Law, Finance, and Ethics	3
CE 484	Water Treatment Design	3
CE 485	Waste Water Treatment Design	3
ENE 400	Introduction to Environmental Engineering Principles	3
ENE 410	Environmental Fluid Mechanics	3
ENE 428	Air Pollution Fundamentals	3
ENE 486	Design of Solid and Hazardous Waste Engineering Systems	3

Courses from other departments

CHE 330	Chemical Engineering Thermodynamics	4
GEOL 305xL	Introduction to Engineering Geology	4
		56

MAJOR REQUIREMENTS (TRACK I ONLY)		UNITS
CE/ENE Engineering courses		
ENE 429	Air Pollution Control	3

Courses from other departments

BISC 220L	General Biology: Cell Biology and Physiology	4
PTE 463L	Introduction to Transport Processes in Porous Media	3
		10

MAJOR REQUIREMENTS (TRACK II ONLY)		UNITS
CE/ENE Engineering Courses		
ENE 487	Environmental Biotechnology and Bioremediation	3

Courses from other departments

BISC 320L	Molecular Biology	4
BISC 330L	Biochemistry	4
		11

MAJOR ELECTIVES (TRACK I ONLY)	UNITS
Design Kernel***	3
Total (Track I):	132
Total (Track II):	134

*Taken concurrently

**Satisfies general education requirement for Category III

*** Kernels must be selected from the following design courses: CE 443, CE 466, CE 476, or CHE 442

Bachelor of Science in Civil Engineering (Information Management) (134 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, CE 225, CE 309 and CE 325. See also the common requirements for undergraduate degrees, page 518.

FIRST YEAR, FIRST SEMESTER		UNITS
CE 106	Design and Planning of Civil Engineering Systems	2
CHEM 105aL	General Chemistry, or	
CHEM 115aL	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
CSCI 101L	Fundamentals of Computer Programming	3
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
		14

SECOND YEAR, FIRST SEMESTER		UNITS
CE 205	Statics	2
CSCI 102L	Data Structures	4
MATH 226	Calculus III	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetics	4
General education		4
		18

SECOND YEAR, SECOND SEMESTER		UNITS
CE 225	Mechanics of Deformable Bodies	3
CE 460	Construction Engineering	3
CSCI 201L	Principles of Software Development	4
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
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3
CE 358	Theory of Structures I	3
General education		4
General education		4
		17

THIRD YEAR, SECOND SEMESTER		UNITS
CE 334L	Mechanical Behavior of Materials	3
CE 402	Computer Methods in Engineering	3
GEOG 381L	Geographic Information Science	4
WRIT 340	Advanced Writing Course	3
Design**	Design elective #1	3
		16

FOURTH YEAR, FIRST SEMESTER		UNITS
CE 408	Risk Analysis in Civil Engineering	3
CE 467L	Geotechnical Engineering	4
CE 471	Principles of Transportation Engineering	3
CE 477	Civil Infrastructure Information Systems	3
Design**	Design elective #2	3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CE 480	Structural Systems Design	3
CE elective		3
CSCI 485	File and Database Management, or	
IOM 435	Business Database Systems	4
Design**	Design elective #3	3
General education		4
		17

*Taken concurrently.

**The Design electives must be selected from the following courses: CE 409a, CE 456, CE 457, CE 478, CE 465, and CE 476.

***Satisfies a general education requirement for Category III.

One general education elective must also satisfy the diversity requirement or additional units will be required.

Minor in Environmental Engineering
See listing on page 587.

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 404x, 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
PPD 358	Urban and Regional Economics	4
PPD 362	Real Estate Fundamentals for Planning and Development	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
PPD 437	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 PPD 437 must have completed PPD 358.

Accelerated Dual Degrees
The following accelerated degrees may be earned in five years: B.S., Civil Engineering/M.S. Civil Engineering (Construction Engineering); B.S., Civil Engineering/Master of Construction Management; B.S., Civil Engineering (Building Science)/M.S., Civil Engineering (Structural Engineering); B.S., Civil Engineering (Building Science)/M.Eng., Structural Design; B.S., Civil Engineering (Construction Engineering)/M.S., Civil Engineering (Constructing Engineering); B.S. Civil Engineering (Construction Engineering)/Master of Construction Management; B.S. Civil Engineering (Environmental Engineering)/M.S. Environmental Engineering; B.S. Civil Engineering

(Structural Engineering)/M.S. Civil Engineering (Structural Engineering); B.S., Civil Engineering (Structural Engineering); M.Eng., Structural Design; and B.S., Environmental Engineering/M.S., Civil Engineering.

The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 overall or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of the graduate courses during their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to 6 units of course work will be counted toward satisfying the unit requirements of both programs. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

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 Viterbi 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; geotechnical engineering; structural engineering; environmental engineering; and transportation engineering. Students specializing in the transportation option and completing a thesis must include in their program 4 units of CE 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 Public Administration Professional Sequence section in the School of Policy, Planning, and Development, page 813.

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) AME 530ab, CE 507, CE 508, CE 525ab, and CE 541b; (2) at least six units of electives from the following: CE 541a, CE 542, CE 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 Engineering in Environmental Quality Management
Environmental engineers with purely scientific and technological backgrounds are often excluded from certain high-level professional managerial positions in the manufacturing industry, public utilities or governmental agencies, although they are generally preferred for engineering, scientific and research positions. Their exclusion from these positions is often attributed to inadequate preparation in areas deemed important in recent years, including the following: project management, regulatory compliance, strategic and financial planning, decision making and human relations. Thus, effective and efficient management of modern environmental engineering projects requires broad technical knowledge and diverse skills in the above aspects. The Master of Engineering degree program in Environmental Quality Management intends to bridge the gap between the essentials of hard-core engineering and project management. The program is intended to provide the student with cutting edge instruction in the art and science of environmental management. It is also directed at teaching and training students how to integrate environmental considerations in the early planning of projects to improve environmental compatibility, reduce risks and incur financial savings in businesses and industries.

REQUIRED CORE COURSES		UNITS
ENE 495	Seminars in Environmental Engineering	1
ENE 510	Water Quality Management and Practice	3
ENE 518	Environmental Systems Engineering and Management	3
ENE 535	Applied Air Quality Management	3
MPW 950	Technical Writing	3
		13

ENGINEERING ELECTIVE OPTION		
(TECHNICAL ELECTIVE COURSES; CHOOSE ONE)		UNITS
CE 504	Solid Waste Management	3
CSCI 576	Multimedia Systems Design	3
ENE 502	Environmental and Regulatory Compliance	3
ENE 505	Energy and Environment	3
ENE 506	Ecology for Environmental Engineers	3
ENE 516	Hazardous Waste Management	3
ENE 526	Environmental Pollutants: Monitoring and Risk Assessment	3

BUSINESS COMMUNICATION/MANAGEMENT AND		
ORGANIZATION ELECTIVE (CHOOSE ONE)		UNITS
BUCO 445	Oral Communication in Business	4
BUCO 485	Business Communication Management	4
MOR 469	Negotiation and Persuasion	4

BUSINESS ADMINISTRATION AND ENTREPRENEURSHIP/		
MANAGEMENT AND ORGANIZATION ELECTIVE		
(CHOOSE ONE)		UNITS
BAEP 451	The Management of New Enterprises	4
MOR 462	Management Consulting	4

PROJECT COURSE		UNITS
ENE 590	Directed Research	6

The approved project work will be a research activity designed for about 3-4 months during the summer period, performed by the student under the direction and supervision of a full-time faculty member. The work will involve the participation of leading professionals from the private industry and/or governmental agencies with whom the faculty member might maintain a professional relationship. The project will address an area of importance and primary interest to the industrial entity in question. It is believed that this type of partnership will be mutually beneficial to the graduating student, private industry and university faculty in generating a friendly and long-term professional relationship among them.

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 inter-disciplinary 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.

Applicants to the program are expected to have completed undergraduate course work in engineering economy or business finance.

CORE CURRICULUM		UNITS
ARCH 511L	Seminar: Building Systems	4
CE 501	Functions of the Constructor	3
CE 502	Construction Accounting and Finance, or	
GSBA 510	Accounting Concepts and Financial Reporting	3
CE 556ab	Project Cost Estimating, Control, Planning and Scheduling	3-3
RED 509	Market Analysis for Real Estate, or	
RED 598	Real Estate Project Development	4
RED 542	Finance of Real Estate	3
Additional advisor approved technical and advanced electives		10
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 Gould School of Law 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 783.

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 563.

Master of Engineering in Structural Design
The Master of Engineering program emphasizes the design of engineered structural systems. The design of new structures and the upgrading of existing structures, for adverse loading conditions, requires additional studies which extend beyond the basic concepts stressed in an undergraduate program. Modern computational methods will be used to evaluate the functional demands on the designed system, and a comprehensive design project will be used to integrate the concepts presented during the course of study. The program is focused on the needs of students who are planning to enter professional practice and not continue for a more advanced degree and on the needs of practicing engineers who have been out of school for several years and who want to upgrade their engineering skills.

The course of study requires the successful completion of 30 semester units. It is designed to be completed in one year of study, including the design project which must be taken during the first, seven-week summer session.

REQUIRED COURSES (18 UNITS)		UNITS
CE 458	Theory of Structures II, or	
CE 488	Computer Applications in Structural Analysis and Design	3
CE 459	Introduction to Structural Dynamics	3
CE 537	Advanced Reinforced Concrete	3
CE 538	Prestressed Concrete	3
CE 539	Advanced Steel Structures	3
CE 549	Building Design Project	3

ELECTIVE COURSES (4 COURSES, 12 UNITS)		UNITS
CE 480	Structural Systems Design	3
CE 482	Foundation Design	3
CE 501	Function of the Constructor	3
CE 525b	Engineering Analysis	3
CE 528	Seismic Analysis and Design of Reinforced Concrete Bridges	3
CE 536	Structural Design for Dynamic Loads	3
CE 540	Limit Analysis of Structures	3

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 (CAE) 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 564.

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 404x 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
PPD 633	Urban Transportation Planning and Management	4
PPD 634	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 (3, Fa) Basic concepts of environmental engineering. Air, water, and soil pollution control technologies; pollution prevention strategies. Design of simple water distribution and treatment systems.

205 Statics (2, FaSp) Statics of particles and rigid bodies; equivalent force systems; distributed forces; applications to trusses, frames, machines, beams, and cables; friction; moments of inertia. *Prerequisite:* PHYS 151*L*.

207L Introduction to Design of Structural Systems (2, Sp) Structural materials, components and systems; gravity and lateral forces; structural performance and failures; introduction to structural plans and analysis; computer applications, case studies, design project. *Prerequisite:* CE 107, CE 205; *corequisite:* CE 225.

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. *Corequisite:* CHEM 105*aL* or CHEM 115*aL; recommended preparation:* CE 110.

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, Fa) 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 226; *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. *Prerequisite:* CE 225, MATH 226.

409abL Computer-Aided Design (3-3, Fa) 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 Construction Law and the Property Development Process (3, Fa) Legal aspects of property development and construction: land use, construction practices and specifications, architecture and engineering contracts, agency, subcontracting, professional registration, liability, insurance, liens, and bonds. *Recommended preparation:* CE 404 or a general business law course.

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:* AME 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 (3, Sp) Discussion of broad perspectives on control and utilization of water, quantitative hydrology, ground water, probability concept, economic study, hydraulic structures, multipurpose water resources projects. *Prerequisite:* CE 309 or ENE 410.

453 Water Quality Control (3, Fa) 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*; CE 309 or ENE 410; *corequisite:* CE 408 or CHE 405.

456 Design of Steel Structures (3, Fa) Fundamentals of analysis and design of steel structures; structural elements; simple and eccentric connections; design project. *Prerequisite:* CE 207*L*, CE 225; *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 AME 150*L* and AME 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. Junior or senior standing.

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.

473 Engineering Law, Finance and Ethics (3, Sp) An examination of the legal, financial and ethical issues regularly considered by all practicing engineers. Upper division standing.

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.

477 Civil Infrastructure Information Systems (3, Fa) Information systems and their use in the planning, design, construction, and operation of civil infrastructure projects. Project management and knowledge management for infrastructure systems development. *Prerequisite:* CSCI 201, CE 402.

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 or CE 457 or CE 478; CE 358, CE 467*L*, CE 473, CE 482.

482 Foundation Design (3) Analysis and design principles of building foundations, including spread footings, piles, drilled shafts, sheetpile walls and retaining structures. *Prerequisite:* CE 467.

484 Water Treatment Design (3, Fa) 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 463*L*, CE 473.

485 Wastewater Treatment Design (3, Sp) 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 463*L*, CE 473.

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:* AME 530*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.

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.

549 Building Design Project (3, Sm) Integrated design project following design office procedures. A building will be designed in detail using the team approach. Capstone for M.Eng. in Structural Design. *Prerequisite:* CE 488 or CE 458, CE 537, CE 539, CE 549.

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, Control, Planning, and Scheduling (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 and regional 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.

579 Introduction to Transportation Planning Law (3) Federal and state statutory and regulatory requirements affecting California transportation systems, including transportation planning and funding law; and government contracting, environmental, and civil rights requirements.

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. *Recommended preparation:* CE 471.

586x Management for Engineers (4) (Enroll in AME 589*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.

589 Port Engineering: Planning and Operations (3, Sp) Physical and operational characteristics of marine ports; impact analysis of modern logistics on port operation, planning and management; optimization and efficiency solutions for container terminals.

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.

633 Urban Transportation Planning and Management (4, 2 years, Fa) (Enroll in PPD 633).

634 Institutional and Policy Issues in Transportation (4, Sp) (Enroll in PPD 634).

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 Viterbi 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 AME 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. AME 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 AME or CE 590 directed research courses through an appropriate advisor.

CAE CORE CURRICULUM		UNITS
AME 526	Engineering Analytical Methods, or	
CE 525b	Engineering Analysis	3
AME 535a	Introduction to Computational Fluid Mechanics, or	
CE 529a	Finite Element Analysis	3
AME 535b	Introduction to Computational Fluid Mechanics, or	
AME 590	Directed Research, or	
CE 551	Computer-Aided Engineering Project, or	
CE 590	Directed Research	3
CE 550	Computer-Aided Engineering	3
CSCI 455x	Introduction to Programming Systems Design	4

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 Aerospace and Mechanical Engineering and Civil 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		UNITS
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
AME 535a	Introduction to Computational Fluid Mechanics, or	
CE 529a	Finite Element Analysis	3
AME 535b	Introduction to Computational Fluid Mechanics, or	
CE 551	Computer-Aided Engineering Project	3
CE 550	Computer-Aided Engineering	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

Education Program Objectives

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 128 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.

In addition, CECS majors must complete a minimum of 30 units of course work in Humanities and Social Sciences.

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.

FIRST YEAR, FIRST SEMESTER		UNITS
EE 106L	Introduction to Computer Engineering/Computer Science	3
MATH 125	Calculus I	4
WRIT 140*	Writing and Critical Reasoning	4
General Education Category VI*		4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CSCI 101L	Fundamentals of Computer Programming	3
EE 101	Introduction to Digital Logic	3
MATH 126	Calculus II	4
General Education Category V		4
Free elective		2
		16

SECOND YEAR, FIRST SEMESTER		UNITS
CSCI 105	Object-Oriented Programming	2
EE 201L	Introduction to Digital Circuits	2
MATH 226	Calculus III	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
General Education Category II		4
		16

SECOND YEAR, SECOND SEMESTER		UNITS
CSCI 102L	Data Structures	3
EE 357	Basic Organization of Computer Systems	3
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
MATH 225	Linear Algebra and Differential Equations	4
General Education Category I		4
		18

THIRD YEAR, FIRST SEMESTER		UNITS
CSCI 201L	Principles of Software Development	4
CSCI 271	Discrete Methods in Computer Science	3
EE 328Lx	Circuits and Electronics for Computer Engineers	4
EE 457x	Computer Systems Organization	3
Free elective		2-3
		16-17

THIRD YEAR, SECOND SEMESTER		UNITS
CSCI 303	Design and Analysis of Algorithms	3
EE 364	Introduction to Probability and Statistics for Electrical Engineering, or	3
MATH 407	Probability Theory	4
EE 454L	Introduction to Systems Using Microprocessors	4
General Education Category IV+		4
Technical elective***		3
		17-18

FOURTH YEAR, FIRST SEMESTER		UNITS
CSCI 377	Introduction to Software Engineering	3
CSCI 402	Operating Systems	3
WRIT 340	Advanced Writing	3
Science elective****		4
Technical elective***		3
		16

FOURTH YEAR, SECOND SEMESTER		UNITS
CSCI 477	Design and Construction of Large Software Systems, or	
EE 459L	Embedded Systems Design Laboratory	3
ISE 460	Engineering Economy	3
400-level math elective++		4
Technical elective***		3
		13
Minimum total units for degree		128

* Taken concurrently.

** Satisfies general education requirement for category III.

*** Three courses are required. Applicable courses include: CSCI 351, CSCI 377, CSCI 410x, CSCI 445, CSCI 459, CSCI 460, CSCI 477L, CSCI 480, CSCI 485, CSCI 490x, CSCI 499; EE 321, EE 450, EE 459L, EE 465, EE 469, EE 477L, EE 478L, EE 479, EE 490x, EE 499; MATH 458. Other courses may be applicable; please see an advisor for approval.

**** Any course in physics, biology or chemistry beyond the basic science requirement or in another scientific discipline. See department for approval.

+The university allows Engineering majors to replace the General Education Category IV with a second course in Categories I, II, or VI. Choosing this option is the most efficient way to satisfy the 30-unit requirement in Humanities and Social Sciences.

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

Accelerated Dual Degree Programs: Bachelor of Science in Computer Engineering and Computer Science/Master of Science in Computer Engineering; Bachelor of Science in Computer Engineering and Computer Science/Master of Science in Computer Science

Two accelerated dual degrees are offered: B.S., Computer Engineering and Computer Science/M.S., Computer Engineering and B.S., Computer Engineering and Computer Science/M.S., Computer Science.

The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to six units of course work will be counted toward satisfying the unit requirements of both degrees for the B.S., Computer Engineering and Computer Science/M.S., Computer Engineering accelerated dual degree program. Up to nine units of course work will be counted toward satisfying the unit requirements for the B.S., Computer Engineering and Computer Science/M.S., Computer Science accelerated dual degree program. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

Minor in Multimedia and Creative Technologies
See listing under Multimedia and Creative Technologies, page 604.

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 455x	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	3
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	4

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, EE 552, EE 599, EE 658, EE 680, EE 681.

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

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 560, EE 577b, 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 specialization in VLSI must take 6 units from the VLSI breadth list.

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

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

Networks: CSCI 565, CSCI 570, EE 504L, EE 533a, EE 536, EE 552, EE 554, EE 577b, EE 657, EE 658, EE 659, EE 680, EE 681, SAE 549.

VLSI: CSCI 551, CSCI 565, CSCI 570, EE 550, EE 554, EE 555, EE 657, EE 658, EE 659, EE 680, EE 681, SAE 549.

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 Viterbi 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 Networks) degrees section, see page 579.

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	Advanced Topics in Microarchitecture	3
EE 657	Parallel and Distributed Computing	3
EE 659	Interconnection Networks	3

ARTIFICIAL INTELLIGENCE		UNITS
CSCI 544	Natural Language Processing	3
CSCI 561	Foundations of Artificial Intelligence	3
CSCI 574	Computer Vision	3
CSCI 674a	Advanced Topics in Computer Vision	3
EE 559	Mathematical Pattern Recognition	3

ROBOTICS		UNITS
AME 541	Linear Control Systems II	3
AME 548	Analytical Methods in Robotics	3
CSCI 545	Robotics	3
CSCI 547	Sensing and Planning in Robotics	3

COMPUTER NETWORKS AND DISTRIBUTED SYSTEMS		UNITS
CSCI 551	Computer Communications	3
CSCI 555	Advanced Operating Systems	3
EE 450	Introduction to Computer Networks	3
EE 532	Wireless Internet and Pervasive Computing	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 560	Digital System Design – Tools and Techniques	3
EE 577ab	VLSI System Design	3-2
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

Henry Salvatori Computer Science Center 300
(213) 740-4494
FAX: (213) 740-7285
Email: csdept@pollux.usc.edu

Chair: Gerard Medioni, Ph.D.

Faculty

Gordon S. Marshall Chair in Engineering: Aristides Requicha, Ph.D.

Henry Salvatori Chair in Computer Science: Leonard Adleman, Ph.D.

Fletcher Jones Chair in Computer Science: Michael Arbib, Ph.D.

Charles Lee Powell Chair in Engineering: Ulrich Neumann, Ph.D.

Charles Lee Powell Chair in Electrical Engineering and Computer Science: 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.

Gabilan Assistant Professorship in Computer Science: Banu Ozden, Ph.D.

Professors: Leonard Adleman, Ph.D. *(Molecular Biology);* Michael Arbib, Ph.D. *(Biomedical Engineering, Electrical Engineering);* Barry Boehm, Ph.D. *(Industrial and Systems Engineering);* Ellis Horowitz, Ph.D. *(Electrical Engineering);* Ming-Deh Huang, Ph.D.; Dennis McLeod, Ph.D.; Gerard Medioni, Ph.D. *(Electrical Engineering);* Ramakant Nevatia, Ph.D. *(Electrical Engineering);* Aristides Requicha, Ph.D. *(Electrical Engineering);* Paul Rosenbloom, Ph.D.; Christoph Von Der Malsburg, Ph.D.

Associate Professors: Shahram Ghandeharizadeh, Ph.D.; Leana Golubchik, Ph.D. *(Electrical Engineering);* Ramesh Govindan, Ph.D.; Sven Koenig, Ph.D.; Maja Mataric, Ph.D. *(Neuroscience Center);* Neno Medvidovic, Ph.D.; Aiichiro Nakano, Ph.D. *(Biomedical Engineering, Materials Science, Physics);* Ulrich Neumann, Ph.D. *(Electrical Engineering);* Stefan Schaal, Ph.D. *(Neuroscience Center);* Cyrus Shahabi, Ph.D.; Gaurav Sukhatme, Ph.D. *(Electrical Engineering)*; Milind Tambe, Ph.D.

Assistant Professors: Laurant Itti, Ph.D.; David Kempe, Ph.D.; Banu Ozden, Ph.D.; Christos Papadopoulos, Ph.D.

Joint Professors: Joseph Bannister, Ph.D. *(Electrical Engineering);* Irving Biederman, Ph.D. *(Psychology);* Edward Blum, Ph.D. *(Mathematics);* Melvin Breuer, Ph.D. *(Electrical Engineering);* Todd Brun, Ph.D.; Tim Ting Chen, Ph.D. *(Computational Molecular Biology);* Kai Hwang, Ph.D. *(Electrical Engineering);* Rajiv Kalia, Ph.D. *(Physics);* Bhaskar Krishnamachari, Ph.D. *(Electrical Engineering);* Stephen Lu, Ph.D. *(Industrial and Systems Engineering);* Shri Narayanan, Ph.D. *(Electrical Engineering);* Viktor Prasanna, Ph.D. *(Electrical Engineering);* Konstantinos Psounis, Ph.D.; C.S. Ragavendra, Ph.D. *(Electrical Engineering);* Irving Reed, Ph.D. *(Electrical Engineering);* Priya Vashishta, Ph.D. *(Material Science, Physics);* Michael Waterman, Ph.D. *(Mathematics);* Richard Weinberg, Ph.D. *(Cinema/Television)*

Adjunct Professor: Sukhan Lee, Ph.D.

Adjunct Associate Professors: Steve Chien, Ph.D.; Zhengyou Zhang, Ph.D.

Adjunct Assistant Professors: Steve Jacobs, Ph.D.; Larry Matthies, Ph.D.; Xin Wang, Ph.D.

Research Professor: Herbert Schorr, Ph.D.

Research Associate Professors: Yolanda Gil, Ph.D.; Mary Hall, Ph.D.; John Heidemann, Ph.D.; Eduard Hovy, Ph.D.; Lewis Johnson, Ph.D.; Carl Kesselman, Ph.D.; Kevin Knight, Ph.D.; Craig Knoblock, Ph.D.; Robert Neches, Ph.D.; William Swartout, Ph.D.

Research Assistant Professors: Ann L. Chervenak, Ph.D.; Isaac Cohen, Ph.D.; Paul Cohen, Ph.D.; Paul Debevec, Ph.D.; Steven Decker, Ph.D.; Ewa Deelman, Ph.D.; Pedro Diniz, Ph.D.; Alexandre Francois, Ph.D.; Martin Frank, Ph.D.; Andrew Gordon, Ph.D.; Jonathan Gratch, Ph.D.; Randall Hill, Ph.D.; Jerry Hobbs, Ph.D.; Andrew Howard, Ph.D.; Lewis Johnson, Ph.D.; Carl Kesselman, Ph.D.; Jihie Kim, Ph.D.; Craig Knoblock, Ph.D.; Kristina Lerman, Ph.D.; Rajiv Maheswaran, Ph.D.; Stacey Marsella, Ph.D.; Daniel Marcu, Ph.D.; Dan Massey, Ph.D.; Clifford Neuman, Ph.D.; Fred Pighin, Ph.D.; Herbert Schorr, Ph.D.; Wei-Min Shen, Ph.D.; Pedro Szekely, Ph.D.; Joseph Touch, Ph.D.; David Traum, Ph.D.; Michael Van Lent, Ph.D.; Suya You, Ph.D.; Roger Zimmerman, Ph.D.

Lecturers: Claire Bono; Michael Crowley, Ph.D.; Massoud Ghyám-Khah; David Wilczyrski, Ph.D.

Emeritus Professors: George Bekey, Ph.D. *(Electrical Engineering, Biomedical Engineering);* 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 Viterbi 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 pages 60 and 219.

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 VI*		4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
CSCI 105	Object Oriented Programming	2
CSCI 107	Computers and Society	3
MATH 126	Calculus II	4
General education V		4
Foreign language I		4
		17

SECOND YEAR, FIRST SEMESTER		UNITS
CSCI 102L	Data Structures	4
EE 101	Introduction to Digital Logic	3
MATH 226	Calculus III	4
Foreign language II		4
Free elective		2
		17

SECOND YEAR, SECOND SEMESTER		UNITS
CSCI 201L	Principles of Software Development	4
CSCI 271	Discrete Methods in Computer Science	3
EE 201L	Introduction to Digital Circuits	2
MATH 225	Linear Algebra and Differential Equations	4
Foreign language III		4
		17

THIRD YEAR, FIRST SEMESTER		UNITS
CSCI 303	Design and Analysis of Algorithms	3
EE 357	Basic Organization of Computer Systems	3
MATH 407	Probability Theory, or	4
EE 364	Introduction to Probability and Statistics for Electrical Engineering	3
Technical elective I		3
Basic science requirement I**		4
		16-17

THIRD YEAR, SECOND SEMESTER		UNITS
CSCI 377	Introduction to Software Engineering	3
EE 457x	Computer Systems Organization	3
General education IV		4
Technical elective II		3
Basic science requirement II **		4
		17

FOURTH YEAR, FIRST SEMESTER		UNITS
CSCI 402x	Operating Systems	3
General education I		4
Science elective***		4
Free elective		4
		15

FOURTH YEAR, SECOND SEMESTER		UNITS
CSCI 477	Design and Construction of Large Software Systems	3
WRIT 340	Advanced Writing	3
General education II		4
Free elective		3
		13

*Taken concurrently.

**Basic science requirement: PHYS 151L and PHYS 152L or CHEM 105aLbL or BISC 120L and BISC 220L.

***Any course in physics, biology or chemistry beyond the basic science requirement or in another scientific discipline. See department for approval.

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 (two courses)
Applicable courses include: CSCI 351, CSCI 410, CSCI 445, CSCI 459, CSCI 460, CSCI 464, CSCI 480, CSCI 485, CSCI 490x, CSCI 499; EE 321, EE 450, EE 454L, EE 459L, EE 465, EE 477L, EE 490x, EE 499; MATH 458. Other courses may be applicable; please see an advisor for approval.

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 386 for course requirements.

Bachelor of Science in Computer Engineering and Computer Science
See the listing under Computer Engineering, page 564.

Minor in Computer Science
The computer science minor introduces the concepts, tools and techniques that are involved in the programming of computers. The minor prepares students to achieve mastery in several current programming languages. In addition, the student will learn about creating effective user interfaces and how to build applications that are available on the World Wide Web.

REQUIRED COURSES (22 UNITS)

Lower division (16 units)
CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	4
CSCI 105	Object-Oriented Programming	2
CSCI 107	Computers and Society	3
CSCI 201L	Principles of Software Development	4

Upper division (6 units)
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 377	Introduction to Software Engineering	3

ELECTIVES

10 units selected from the following courses:

CSCI 445	Introduction to Robotics	4
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477	Design and Construction of Large Software Systems	3
CSCI 480	Computer Graphics	3
CSCI 485	File and Database Management	3
CSCI 499	Special Topics	2-4

Total: 32 units

Note: Students majoring in business may wish to take CSCI 477 and CSCI 485: These courses will prepare them to utilize computers in a corporate setting.

Students majoring in fine arts or cinema-television may wish to take CSCI 460 and CSCI 480: These courses will prepare them to apply computers to movies and online games.

Students majoring in chemistry or physics may prefer to take CSCI 445 and CSCI 460: These courses will prepare them to create sophisticated software for scientific applications.

Minor in Multimedia and Creative Technologies
See listing under Multimedia and Creative Technologies, page 604.

Accelerated Dual Degree Programs: Bachelor of Science in Computer Engineering and Computer Science/Master of Science in Computer Engineering; Bachelor of Science in Computer Engineering and Computer Science/Master of Science in Computer Science
Two accelerated dual degrees are offered: B.S., Computer Engineering and Computer Science/M.S., Computer Engineering and B.S., Computer Engineering and Computer Science/M.S., Computer Science.

The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to nine units of course work will be counted toward satisfying the unit requirements of both degrees for the B.S., Computer Engineering and Computer Science/M.S., Computer Engineering accelerated dual degree program. Up to nine units of course work will be counted toward satisfying the unit requirements for the B.S., Computer Engineering and Computer Science/M.S., Computer Science accelerated dual degree program. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

Graduate Degrees

The requirements listed below are special to this department and must be read in conjunction with the general requirements of the USC Viterbi School of Engineering for master's degrees and the general requirements of the USC Graduate School for Ph.D. degrees, page 91. 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 Intelligent Robotics 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 605.

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 359.

A master of science in integrated media systems is offered. See the listing under Multimedia and Creative Technologies, page 605.

Admission and Prerequisites
Admission is determined by the Office of Admission 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, CSCI 102L, CSCI 201L, EE 101, 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 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 in Computer Science
Requirements for Graduation without a Thesis
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, CSCI 561 or CSCI 573, CSCI 565, CSCI 571, CSCI 577a and CSCI 585. A maximum of 9 units may be taken at the 400 level from approved courses 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 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 Viterbi School of Engineering master's degrees.

Thesis Option
With the approval of a supervising professor, qualified students may be allowed to pursue a thesis option. Students pursuing the thesis option must satisfy all of the policies and course requirements for the master's degree with the following exceptions: A maximum of six units from approved courses may be taken at the 400 level in either electrical engineering or computer science; and CSCI 590 maybe counted for a maximum of 2 units.

In addition, these students must enroll in a minimum of two semesters of CSCI 594*abz* for a maximum of 4 units. Total units required for the degree is 27. The thesis must comply with all requirements set by the Graduate School. The thesis option is available to students pursuing degrees in the following programs: M.S. in Computer Science and M.S. in Computer Science with specializations in computer networks, software engineering, intelligent robotics, multimedia and creative technologies, and computer security.

Master of Science in Computer 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 450, CSCI 551, CSCI 555 and three of the following: CSCI 558; CSCI 599 or CSCI 694a or CSCI 694b; EE 549, EE 550 and EE 555. 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 with a Specialization in Computer Security
Students must satisfy all the requirements for the Master of Science degree in Computer Science. In addition they must take the following courses: CSCI 530, CSCI 551, CSCI 555, CSCI 577a or CSCI 578 (CSCI 555 and CSCI 577a may be used to satisfy both the general master's degree requirements and the specialization requirements); plus three of the following elective courses: CSCI 556, CSCI 558L, CSCI 570, CSCI 578, CSCI 599 (topic must be approved), and CSCI 694a or CSCI 694b. Total units required for the degree is 27.

Master of Science in Computer Science with Specialization in Higher Performance Computing Simulations
Students in the MSCS-HPCS program must satisfy the current core requirements for the Master of Science degree in Computer Science and the following elective courses must be included in the program:

REQUIRED CORE COURSE		UNITS
CSCI 653*	High Performance Computing and Simulations	3

TECHNICAL ELECTIVE COURSES		UNITS

Three of the following courses – students must take courses from both the computer science track and the computational science/engineering application track.

Computer Science Track

CSCI 520	Computer Animation and Simulation	3
CSCI 551*	Computer Communications	3
CSCI 558L	Internetworking and Distributed Systems Laboratory	3
CSCI 580	3-D Graphics and Rendering	3
CSCI 583*	Computational Geometry	3
CSCI 595	Advanced Compiler Design	4
CSCI 596*	Scientific Computing and Visualization	3
EE 653	Advanced Topics in Microarchitecture	3
EE 657*	Parallel and Distributed Computing	3
EE 659*	Interconnection Networks	3
MATH 501	Numerical Analysis and Computing Using Matlab/C++	3

Computational Science/Engineering Application Track

AME 535a*	Introduction to Computational Fluid Dynamics, or	
AME 535b*	Introduction to Computational Fluid Dynamics	3
CE 529a*	Finite Element Analysis	3
CHE 502	Numerical Methods for Diffusive and Convective Transport	3
EE 553*	Computational Solution of Optimization Problems	3
MASC 575*	Basics of Atomistic Simulations of Materials	3
PHYS 516	Methods of Computational Physics	3
PTE 582*	Fluid Flow and Transport Processes in Porous Media	3

Advisor approved remainder of elective units 6

*Courses offered through the Distance Education Network (DEN).

Master of Science in Computer Science (Multimedia and Creative Technologies)
See the listing under Multimedia and Creative Technologies, page 605.

Master of Science in Computer 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, CSCI 577ab and CSCI 578, plus three of the following five courses: CSCI 511, CSCI 555, CSCI 585, CSCI 588 and EE 557 (EE 557, CSCI 555, CSCI 577a, and CSCI 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.

Certificate in Software Engineering

The certificate program prepares software practitioners for lifetime leadership in software-intensive systems. This program is designed for practicing software developers, engineers and technical managers, who typically study off campus while working full-time. The Distance Education Network (DEN) of the Viterbi School of Engineering administers and delivers all courses in the program. Students must complete five 3-unit classes, CSCI 510, CSCI 578, CSCI 591ab and CSCI 592, with a minimum grade of B-, and must complete the program with a minimum average of B (3.0).

Admission and Prerequisites
Applicants must have an undergraduate or graduate degree from an accredited university with a minimum grade point average of 3.0. If the degree is not in engineering, mathematics or science, then the applicant must present work experience adequate to satisfy the program director that the applicant can successfully complete the course work. GRE scores are not required. Applicants should have practical experience developing software or managing software development and working knowledge of C++, Java or an equivalent programming language. Those who lack the practical experience, or language familiarity, may apply to take CSCI 455x Introduction to Programming Systems Design, which must be passed with a grade of B or better.

Applicants to the program must submit the USC graduate application form and official academic transcripts, undergraduate and graduate (if any), to the USC Office of Admission. Applicants who do not have a technical degree but believe they have adequate background to complete the course work successfully must also include a letter requesting special consideration, explaining the circumstances in reasonable detail.

Applicants may begin study as a limited student by submitting the Distance Education Network (DEN) enrollment form along with a resume for evaluation by the program director at least two weeks before the start of the semester.

Limited students may take up to two program classes before applying for admission. A maximum of 12 units taken as a limited student may be transferred toward the unit requirements of the certificate. *Enrollment as a limited student does not guarantee admission to the certificate program.*

The DEN Web site (*den.usc.edu*) has information about applying, enrolling, tuition and fees.

Master of Science in Computer Science with Specialization in Intelligent Robotics

Students must take CSCI 545 and three of the following courses: CSCI 445, CSCI 547, CSCI 584, and CSCI 593. Other requirements are the same as for the Master of Science degree in Computer Science, described above. (CSCI 561 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 Computational Linguistics, page 359.

Master of Science in Integrated Media Systems

See the listing under Multimedia and Creative Technologies, page 605.

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 five groups. Students must complete one class from each group: *Group 1:* EE 557 Computer Systems Architecture, CSCI 551 Computer Communications, CSCI 555 Advanced Operating Systems; *Group 2:* CSCI 577a Software Engineering, CSCI 571 Web Technologies, CSCI 585 Database Systems; *Group 3:* CSCI 545 Robotics, CSCI 561 Foundation of Artificial Intelligence, CSCI 564 Brain Theory and Artificial Intelligence; *Group 4:* CSCI 574 Computer Vision, CSCI 580 Graphics and Rendering, CSCI 582 Geometric Modeling; *Group 5:* CSCI 570 Analysis of Algorithms, CSCI 581 Logic and its Applications, MATH 501 Numerical Anaysis and Computation. A minimum GPA of 3.5 must be obtained in these five core courses.

In addition, all Ph.D. students must register for two semesters of CSCI 597 Seminar in Computer Science Research for a maximum of 2 units during their first year.

Ph.D. programs in computer science are grouped into the following specializations: Network and Systems (Interaction); Databases (Interaction); Software Engineering (Interaction); Robotics (Autonomy); Intelligent Agents and Organizations (Autonomy); Natural Language Processing (Autonomy); Graphics and Multimedia (Immersion); Vision (Immersion); Theory of Computation: Genomic, Molecular and Quantum Computation (Computation); Brain Theory and Neural Networks (Computation); High Performance Computing and Parallel Computation (Computation).

Each student must select a specialization as his or her area of concentration. Each specialization requires a minimum of three additional courses. Specific specialization 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, CSCI 402x, CSCI 410x, EE 457x; 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 Object-Oriented Programming (2, Sp) The principles of object-oriented programming are examined using Java. Topics include graphics, graphical user interfaces and multi-threaded programming. *Prerequisite:* CSCI 101*L*.

106Lx Introduction to Computer Engineering/Computer Science (3, Fa) (Enroll in EE 106Lx)

107 Computers and Society (3, Sp) What computers are and how they function. Impact of computer technology on society. Economic, political and social issues raised by computers.

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 (3, FaSp) Models for discrete structures; finite state automata, regular sets. Selected applications of logic and combinatorics to program correctness, algorithms and complexity, programming language semantics and databases. *Prerequisite:* CSCI 102.

303 Design and Analysis of Algorithms (3, FaSp) Upper and lower bounds on sorting and order median. Deterministic and random computation, data structures, NP-completeness, cryptography, Turing machines and undecidability. *Prerequisite:* CSCI 102 and CSCI 271.

320 Digital Media Basics for Multimedia (3, FaSp) (Enroll in EE 320)

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 102*L*.

357 Basic Organization of Computer Systems (3) (Enroll in EE 357)

377 Introduction to Software Engineering (3, Fa) Introduction of principles, methods, techniques and tools for multi-person construction of multi-version software systems. *Prerequisite:* CSCI 102.

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*; EE 357.

410x Translation of Programming Languages (3, Fa) Concepts of assemblers, compilers, interpreters and their design; macro assemblers, Polish notation and translation techniques; operator precedence parsing, push down automata, code generation. Not available for graduate credit to computer science majors. *Prerequisite:* CSCI 201; *corequisite:* EE 357.

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.

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)

459 Computer Systems and Applications Modeling Fundamentals (3, Sp) Techniques and tools needed to construct/evaluate models of computer systems and applications. Analytical and simulation methods, capacity planning, performance/reliability evaluation, and decision-making. *Prerequisite:* MATH 225, CSCI 201.

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*.

464 Foundations of Exotic Computation (3, Sp) Introduction to new approaches to computation: quantum – inspired by quantum mechanics; neural – inspired by the study of the brain; and molecular – inspired by the genome. *Prerequisite:* MATH 225 or MATH 245 or EE 241.

465 Probabilistic Methods in Computer Systems Modeling (3) (Enroll in EE 465)

477 Design and Construction of Large Software Systems (3, Sp) Programming methodologies; intra-group and inter-group communication; software lifecycle; software economics. A large software project is a central aspect of the course. *Prerequisite:* CSCI 201, CSCI 377.

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.

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, Fa) 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.

520 Computer Animation and Simulation (3, Sp) Fundamental techniques of computer animation and simulation, knowledge and/or experience in the design, scripting, production and post-production stages of computer animation. *Prerequisite:* CSCI 480.

530 Security Systems (4, Sp) Protecting computer networks and systems using cryptography, authentication, authorization, intrusion detection and response. Includes lab to provide practical experience working with such systems. *Prerequisite:* CSCI 402*x*.

533 Combinatorial Analysis and Algebra (3) (Enroll in MATH 533)

541 Artificial Intelligence Planning (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.

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.

543 Software Multiagent Systems (3, Sp) Investigate computational systems in which several software agents or software agents and humans interact. *Prerequisite:* CSCI 561 or CSCI 573.

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 modeling and controlling of dynamic systems for robotic applications and graphics animations; control theory; kinematics; dynamics; sensor processing; real-time operating systems; robot labs. *Prerequisite:* C-programming, basic linear algebra, calculus.

546 Intelligent Embedded Systems (3, Sp) Survey of techniques for the design of large-scale, distributed, networked, embedded systems. Examples include sensor/actuator networks, wearable computing, distributed robotics and smart spaces. Graduate standing in CSCI or EE.

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. Graduate standing in CSCI or EE.

548 Information Integration on the Web (3, Sp) Foundations and techniques in information integration as it applies to the Web, including view integration, wrapper learning, record linkage, and streaming dataflow execution. *Prerequisite:* CSCI 561, CSCI 585; *recommended preparation:* CSCI 571, CSCI 573.

549 Nanorobotics (3, Sp) Introduction to nanotechnology. Nanorobotic systems: sensing; actuation and propulsion; control; communication; power; programming and coordination of robot swarms. Nanomanipulation and nanoassembly with atomic force microscopes. Graduate standing in science or engineering.

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 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*)

561 Foundations of Artificial Intelligence (3, Sp) Foundations of symbolic intelligent systems, search, logic, knowledge representation, planning, learning. *Recommended preparation:* good programming and algorithm analysis skills.

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.

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 573.

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 573.

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 Web Technologies (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, XML and others. *Recommended preparation:* knowledge of at least two programming languages.

573 Advanced Artificial Intelligence (3, Fa) Advanced topics in AI, covering reasoning under uncertainty, decision theory, knowledge-based and inductive learning. *Recommended preparation:* a previous undergraduate or graduate level course in AI. (Duplicates credit in former CSCI 561*b*.)

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*.

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.

580 3-D 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 Mobile Robots and Multi-Robot Systems (3, Sp) Survey of robot control and learning methods from technical papers. Control architectures, adaptation, learning, cooperation, distributed vs. centralized approaches, cooperative and competitive systems. *Prerequisite:* CSCI 445 or CSCI 460 or CSCI 547 or CSCI 561.

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.

589 Software Engineering for Embedded Systems (3, FaSp) Software engineering methods and techniques for embedded, resource constrained, and mobile environments. Applications to real-time operating systems and wireless networking systems. Class project. *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.

591ab Applied Software Engineering (3-3, Sp) *a:* Engineering software systems: negotiating goals; defining life cycle and process; project planning; defining requirements, architecture and design; incorporating COTS; analyzing project artifacts. *b:* Engineering software systems: design, implement, test and maintain software product; management of quality, configuration and transition. Open to Software Engineering Certificate Program students only. (Duplicates credit in CSCI 577*ab*.) *Recommended preparation:* experience in software development.

592 Emerging Best Practices in Software Engineering (3, SpSm) Perspective and experiences with emerging best practices, including integrated maturity models, distributed and mobile software, RAD, agile methods, COTS, assessment and integration, portfolio and product line management. Open to Software Engineering Certificate Program students only. *Recommended preparation:* CSCI 510.

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 573.

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

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.

596 Scientific Computing and Visualization (3, Fa) Hands-on training on the basics of parallel computing and scientific visualization in the context of computer simulations in science and engineering. *Prerequisite:* CSCI 101L or CSCI 455*x*; CSCI 102*L*; MATH 458.

597 Seminar in Computer Science Research (1, max 2, FaSp) Introduction of Ph.D. students to a broad range of computer science research. Two semesters registration required. Open to Computer Science doctoral students only.

599 Special Topics (2-4, max 9) Course content to be selected each semester from recent developments in computer science.

652 Wireless Sensor Networks (3) (Enroll in EE 652)

653 High Performance Computing and Simulations (3, Sp) Advanced high-performance computer simulation techniques; multiscale deterministic and stochastic simulation algorithms on parallel and distributed computing platforms; immersive and interactive visualization of simulation data. *Prerequisite:* CSCI 596 or CSCI 580.

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.

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.

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
(213) 740-4446
FAX: (213) 740-4449
Email: eesystem@ee.usc.edu

Electrical Engineering-Electrophysics
Powell Hall of Information Sciences and
Engineering 604
(213) 740-4700
FAX: (213) 740-8677
Email: eepdept@usc.edu

Co-Chairs: Cauligi Raghavendra, Ph.D.
(Systems); John Choma, Ph.D. *(Electrophysics)*

Associate Chair (Systems): Antonio Ortega, Ph.D.

Associate Chair (Curriculum): Edward Maby,
Ph.D.

Faculty
Presidential Chair in Engineering: Andrew J.
Viterbi, 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.

Fred W. O'Green Chair in Engineering: Leonard
M. Silverman, Ph.D.

George T. Pfleger Chair in Electrical Engineering:
Robert W. Hellwarth, Ph.D. *(Physics)*

Charles Lee Powell Chair in Engineering: Ulrich
Neumann *(Computer Science)*

*Charles Lee Powell Chair in Electrical Engineering
and Computer Science:* Melvin Breuer, Ph.D.
(Computer Science)

*Andrew and Erna Viterbi Chair in Communica-
tions:* Solomon W. Golomb, Ph.D.

Fred H. Cole Professorship in Engineering:
Robert A. Scholtz

*William M. Hogue Professorship in Electrical
Engineering:* William H. Steier, 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,
Ph.D.*; P. Daniel Dapkus, Ph.D. *(Materials
Engineering)*; Michel Dubois, Ph.D.*;* Jack
Feinberg, Ph.D. *(Physics);* Robert M.
Gagliardi, Ph.D.; Solomon W. Golomb, Ph.D.
(Mathematics); Martin Gundersen, Ph.D.
(Materials Engineering, Physics); Sandeep
Gupta, Ph.D.; Robert W. Hellwarth, Ph.D.
(Physics); Tomlinson Holman, B.S. *(Cinema-
Television);* Ellis Horowitz, Ph.D. *(Computer
Science);* Kai Hwang, Ph.D. *(Computer Science);*
Petros Ioannou, Ph.D.; Keith Jenkins, Ph.D.;
Edmond Jonckheere, Ph.D.; Robert Kalaba,
Ph.D. *(Biomedical Engineering and Economics
and Speech Science and Technology);* Thomas
Katsouleas, Ph.D.; Bart Kosko, Ph.D.;
Chung-Chieh Kuo, Ph.D.; P. Vijay Kumar,
Ph.D.; Richard Leahy, Ph.D.* *(Biomedical
Engineering, Radiology);* Anthony F. J. Levi,
Ph.D. *(Physics);* William C. Lindsey, Ph.D.;
Vasilis Z. Marmarelis, Ph.D. *(Biomedical
Engineering);* Gerard Medioni, Ph.D. *(Computer
Science);* Jerry M. Mendel, Ph.D.; Urbashi
Mitra, Ph.D.; Ramakant Nevatia, Ph.D.
(Computer Science); C. L. Max Nikias, Ph.D.;
Alice C. Parker, Ph.D.; Massoud Pedram,
Ph.D.; Timothy Pinkston, Ph.D.; V. Prasanna,
Ph.D. *(Computer Science);* C. Raghavendra,
Ph.D. *(Computer Science);* 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.;
Leonard Silverman, Ph.D.; John Silvester,
Ph.D.; William H. Steier, Ph.D.; Armand R.
Tanguay, Jr., Ph.D. *(Biomedical Engineering,
Materials Science);* Andrew J. Viterbi, 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: Peter Beerel, Ph.D.; Keith
M. Chugg, Ph.D.; Leana Golubchik, Ph.D.
(Computer Science); Eun Sok Kim, Ph.D.;
Christos Kyriakakis, Ph.D.; Shrikanth
Narayanan, Ph.D. *(Computer Science);* Ulrich
Neumann, Ph.D. *(Computer Science);* John
O'Brien, Ph.D.; Antonio Ortega, Ph.D.;
Aluizio Prata, Jr., Ph.D.*

Assistant Professors: Todd Brun, Ph.D.
(Computer Science); Igor Devetak, Ph.D.;
Hossein Hashemi, Ph.D.; Ahmed Helmy,
Ph.D.; Bhaskar Krishnamachari, Ph.D.
(Computer Science); Won Namgoong, Ph.D.;
Krishna Nayak, Ph.D.; Michael Neely,
Ph.D.; Konstantinos Psounis, Ph.D.; Gaurav
Sukhatme, Ph.D. *(Computer Science);*
Chongwu Zhou, Ph.D.

Adjunct Professors: Paul L. Feintuch, Ph.D.;
Eric Fossum, Ph.D.; Dan Goebel, Ph.D.; Kirby
Holte, Ph.D.; Mostafa Shiva, Ph.D.; Monte
Ung, Ph.D.

Adjunct Associate Professors: Serge Dubovitsky,
Ph.D.; James Ellison, Ph.D.; Alan Kost,
Ph.D.; Min-Cheol Oh, Ph.D.; Gandhi
Puvvada, M.S.; Edgar Satorius, Ph.D.; Marvin
Stone, Ph.D.; Ali A. Zahid, M.S.

Adjunct Assistant Professors: Toyone Mayeda,
M.S.; Mark Redekopp, M.S.

Research Professor: Elliot I. Axelbrand, Ph.D.

Research Associate Professors: Joseph Bannister,
Ph.D.; John Granacki, Ph.D.; Laura Marcu,
Ph.D. *(Biomedical Engineering);* Patric Muggli,
Ph.D.; Keith L. Price, Ph.D. *(Computer
Science);* Joe Touch, Ph.D. *(Computer Science)*

Research Assistant Professors: Jeff Draper,
Ph.D.; Panayiotis Georgiou, Ph.D.; Sungbok
Lee, Ph.D.; Bindu Madhavan, Ph.D.

Senior Lecturer: Edward Maby, Ph.D.

Emeritus Professors: Clarence Crowell, Ph.D.
(Materials Science); Alvin Despain, Ph.D.;
Murray Gershenzon, Ph.D.* *(Materials Science);*
Seymour Ginsburg, Ph.D. *(Computer Science);*
Hans H. Kuehl, Ph.D.*; 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

Educational Program Objectives
The electrical engineering program objectives are designed to promote technical competence, professional development and citizenship in the global community.

Technical Competence
Graduates will have the proficiency in mathematics, science and engineering necessary to apply these disciplines to the solution of problems encountered in modern electrical engineering practice.

Graduates will have the ability to model, analyze, design and experimentally evaluate components or systems that achieve desired technical specifications subject to the reality of economic constraints.

Professional Development
Graduates will have the professional skills necessary to compete effectively in a world of rapid technological change as well as to assume leadership roles within industrial, entrepreneurial, academic or governmental environments in the broad context of electrical engineering.

Graduates who have chosen an appropriate plan of study will be capable of professional redirection into such diverse fields as medicine, business, law, computer science, multimedia and music through graduate-level studies and the process of lifelong learning.

Citizenship in the Global Community
Graduates will have the capabilities and communication skills necessary to function effectively both as individuals and as members of multidisciplinary teams in a diverse global economy.

Graduates will have an understanding of the importance of high ethical and professional standards as well as the significance of engineering decisions and solutions in a global, environmental and societal context.

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 518.

FIRST YEAR, FIRST SEMESTER		UNITS
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
EE 105	Introduction to Electrical Engineering	3
MATH 125	Calculus I	4
General education		4
		15

FIRST YEAR, SECOND SEMESTER		UNITS
MATH 126	Calculus II	4
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
WRIT 140*	Writing and Critical Reasoning	4
General education*	Social Issues	4
		16

SECOND YEAR, FIRST SEMESTER		UNITS
CSCI 101L	Fundamentals of Computer Programming	3
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
		18

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 301	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
WRIT 340	Advanced writing	3
Electives	See requirements for graduation	3
		16

THIRD YEAR, SECOND SEMESTER		UNITS
EE 330	Electromagnetics I	3
ISE 460	Engineering Economy, or	
BUAD 301	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
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)
Computer Engineering: EE 201L (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 10 areas of specialization listed below are required:

Communication, Control and Signal Processing
Communications and Networks: EE 401 (3), CSCI 455x (4), (take at least one): EE 450 (3), EE 447L (4/CD*), EE 467x (3)
Signal Processing, Communication and Control Systems (take at least three): EE 434L (4/CD*), EE 467x (3), EE 469 (3), EE 475 (3/D**), EE 482 (3), EE 483 (3), EE 484 (3/CD*)
Controls and Robotics: EE 482 (3) or CSCI 445 (4); (take at least two): EE 401 (3), EE 454L (4/D**), EE 459L (3/CD*)

Computer Engineering
Computer Architecture and Organization:
  EE 454L (4/D**), EE 457x (3),
  EE 459L (3/CD*)
Hardware/Software (take 3 of 4): CSCI 402x
  (3D**), CSCI 455x (4), EE 454L (4/D**),
  EE 457x (3)
Computer Networks (take 3 of 4): CSCI
  402x (3), CSCI 455x (4), EE 450 (3),
  EE 457x (3).

Electromagnetics and Energy Conversion
Energy Conversion: EE 440 (3), EE 442 (3),
  EE 443 (3)
Lasers: EE 471 (3), EE 472 (3), EE 473L
  (3/D**).

Electronic Devices and Circuits
Electronic Circuits (take 3 of 4): EE 447L
  (4/CD*), EE 448L (4/D**), EE 478L
  (4/CD*), EE 479 (3/D**)
Integrated Circuits: EE 438L (3/D**),
  EE 448L (4/D**), EE 477L (4/D**).

Non-EE Engineering Science Elective
At least one elective must be a non-EE engi-
neering science elective, either from the list
below: CE 205, 225, CE 309, CE 325; CHE
472; AME 201, AME 310, AME 452, AME
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 434L*,
EE 438L, EE 447L*, EE 448L, EE 454L,
EE 459L*, EE 473L, EE 475, EE 477L,
EE 478L*, EE 479, EE 484*, including one
of the asterisked capstone design courses.

*CD — Capstone Design Elective
**D — Design Elective

Bachelor of Science in Electrical Engineering (Computers)

The Bachelor of Science in Electrical Engi-
neering (Computers) is earned by successful-
ly completing the normal requirements for
the Bachelor of Science in Electrical Engi-
neering with the following courses chosen as
EE electives: EE 454L; CSCI 455x;
EE 457x; EE 478L.

Bachelor of Science in Computer Engineering and Computer Science

See the listing under Computer Engineering,
page 564.

Bachelor of Science in Electrical Engineering (Integrated Media Systems)

This 131-unit program will expose students
to the creative technology side of multime-
dia. To obtain the BSEE (IMS), the student
must successfully complete the normal
requirements for the Bachelor of Science in

electrical engineering with the following
restrictions: (1) students must take the listed
entry-level electives in the topical areas
of Computer Engineering and Electronic
Devices and Circuits and must also take
EE 241, which will be the entry-level elec-
tive for the topical area of Communication,
Control and Signal Processing; (2) students
must take the following courses within
the Communication, Control and Signal
Processing area of specialization: EE 434L
(4/CD*) (satisfies the capstone design course
requirement), EE 469 (3) and EE 483 (3);
(3) students must take at least two courses
from the following list of design courses:
EE 402, EE 438L, EE 444L, EE 447L,
EE 448L, EE 454L, EE 459L, EE 477L,
EE 478L and EE 479; and, (4) students
must take CSCI 351 (3), CSCI 480 (3) and
EE 450 (3), as technical electives.

It is highly recommended that the student
take EE 483 before the start of the fourth
year, because EE 434L is only taught in the
fall semester.

Industry recommends that students also be
exposed to the creative-artistic side of multi-
media. This can be accomplished (but is not
required) by BSEE (IMS) students taking
the Minor in Multimedia and Creative
Technologies (described on page 604).
Because all of the technical required and
elective courses of that minor will have been
taken as part of the BSEE (IMS), BSEE
(IMS) students can complete this minor by
focusing on the minor's creative artistic
courses — required and elective. Up to six
units from the BSEE (IMS) can be counted
toward this minor.

Minor in Multimedia and Creative Technologies

See listing under Multimedia and Creative
Technologies, page 604.

Minor in Music Recording

A minor in music recording is offered through
the USC Thornton School of Music to pro-
vide undergraduate students with the back-
ground necessary to enter the field of record-
ing engineering and to familiarize them with
the design needs of modern recording equip-
ment. The minor is recommended to electri-
cal engineering majors with extensive musi-
cal 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 Thornton
School of Music, page 733.

Accelerated Dual Degree Program: B.S., Electrical Engineering/M.S., Electrical Engineering

The accelerated dual degree program offers
qualified students the opportunity to simulta-
neously complete the requirements for the
B.S. and M.S. degrees in five years. Students
are eligible for the accelerated dual degree
program upon completing 96 or more units
toward their B.S. with a GPA of 3.2 or higher.
Qualified students who are interested should
see their advisor in their junior year to begin
planning for the inclusion of graduate courses
during their senior year. Students should
apply to the graduate program in the fall of
their senior year. Eligible students will be
automatically accepted to the M.S. degree
program without needing to take the GRE.
All the requirements of both the B.S. and
M.S. degrees must be met; however, up to
9 units of course work will be counted
towards satisfying the unit requirements of
both degrees. In some cases, there may be
limits to the number of 400 level course work
that can be used towards the M.S. degree and
there may be specific course requirements.
Application information may be obtained in
the Viterbi School of Engineering Office of
Admissions and Student Affairs. Students
should see their departmental advisor for
assistance with course selection.

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. Trans-
fer 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
Viterbi School of Engineering, the Master of
Science in Electrical Engineering is also sub-
ject to the following requirements: (1) a total
of at least 27 units is required; (2) every non-
EE course for graduate credit requires prior
written advisor approval recorded each semes-
ter on a special request form 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 require 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 Viterbi 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 res-
idency 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: AME 453 Engineering Dynamics (3); AME 531 Aerodynamics of Wings and Bodies (3); AME 532ab Flight Vehicle Stability and Control (3-3); AME 525 Engineering Analysis (3); AME 526 Engineering Analytical Methods (3); ASTE 580 Orbital Mechanics I (3).

Master of Science in Electrical Engineering (Computer Networks)
Under the computer networks option students must satisfy the M.S., Electrical Engineering requirements with the exception that only 15 units of EE are required. It is expected that each student in this program will take or have taken the equivalent of the following fundamental courses: CSCI 402x, EE 450, EE 457Lx, and EE 465. The following required courses must be included: CSCI 551, EE 549 or EE 550, and EE 555. Suggested elective courses include: CSCI 530, CSCI 555, CSCI 558L, CSCI 570, CSCI 694a, CSCI 694b, EE 532, EE 535, EE 554, EE 557, EE 558, EE 579, EE 590, EE 599, EE 650, EE 652, EE 659. Any other course must be approved by a faculty advisor. Total units required for the degree is 27.

Master of Science in Electrical Engineering (Multimedia and Creative Technologies)
See listing under Multimedia and Creative Technologies, page 606.

Master of Science in Systems Architecture and Engineering
See the listing under Systems Architecture and Engineering, page 612.

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 536a; EE 577a; EE 577b or EE 536b; and EE 552. If a student chooses to take EE 536b *as well* as EE 577b, the student may *either* count EE 536b 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 two courses from one of the following areas and one course from a second area:

Area 1: CSCI 455x, EE 560, EE 577b (see above), EE 658, EE 680 and EE 681.
Area 2: EE 448L, EE 504L, EE 536b (see above), EE 537, EE 581 and EE 630.
Area 3: CSCI 455x, CSCI 570, EE 557, EE 560, EE 577b (see above), EE 659, EE 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, EE 502, EE 504L, EE 506, EE 540, EE 554, EE 560, EE 590, EE 601 and EE 677.

Master of Science in Integrated Media Systems
See listing under Multimedia and Creative Technologies, page 605.

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, EE 571ab, EE 572ab, EE 573ab, EE 575, EE 576, EE 578, EE 604; Plasma Science-EE 539, EE 570ab, EE 572ab; Power and Machinery-EE 510, EE 511, EE 521, EE 524, EE 525, EE 526, EE 527, EE 528; Quantum Electronics-EE 529, EE 530, EE 531, EE 539, EE 540; Solid State-EE 501, EE 502, EE 504L, EE 506, EE 507, EE 508, EE 533, EE 537, EE 601, EE 604, EE 606, EE 607; Integrated Circuits-EE 471, EE 501, EE 504L, EE 506, EE 533, EE 536, EE 537, EE 540, EE 569, EE 577, EE 585, EE 601, EE 604, EE 605, EE 606, EE 630; Optics-EE 529, EE 530, EE 531, EE 539, EE 540, EE 559, EE 566, EE 569, EE 589, EE 642, EE 669.

Major Fields in Electrical Engineering — Systems
Students may major in the following fields: Biomedical Engineering and Biomathematics-EE 593; Communication Theory-EE 535, EE 538, EE 550, EE 551, EE 562ab, EE 563, EE 564, EE 565ab, EE 566, EE 567, EE 568, EE 569, EE 583, EE 595, EE 663, EE 664, EE 666, EE 667, EE 669; Computer Engineering-CSCI 561, EE 532, EE 545, EE 547, EE 548, EE 549, EE 550, EE 552, EE 553, EE 554, EE 555, EE 557, EE 560, EE 574, EE 577ab, EE 578, EE 579, EE 650, EE 653, EE 657, EE 658, EE 677, EE 680, EE 681 (see program listing for the Master of Science in Computer Engineering); Intelligent Systems-EE 559, CSCI 561, CSCI 574; Signal Processing-EE 500, EE 517, EE 519, EE 522, EE 559, EE 562a, EE 566, EE 569, EE 583, EE 586L, EE 589, EE 591, EE 592, EE 596, EE 619, EE 668, EE 669, EE 689; Systems and Controls-EE EE 553, EE 563, EE 585, EE 586, EE 587, EE 588, EE 593.

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; Boolean function synthesis; binary arithmetic; codes; combinational logic devices; sequential circuits; state machine design and implementation.

103L Introduction to Microelectronics (2, Fa)
Laboratory-intensive introduction to basic processes used to fabricate modern integrated circuits. Thin-film growth and deposition, photolithography, integrated-circuit packaging and testing. Process relationship to various disciplines of electrical engineering.

105 Introduction to Electrical Engineering (3, Fa) 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.

106Lx Introduction to Computer Engineering/Computer Science (3, Fa)
Examination of key disciplines of computing systems: architecture, operating systems, digital logic, VLSI, networks, AI, robotics, graphics, and algorithms. Includes hardware/software laboratory tours and exercises.

201L Introduction to Digital Circuits (2, FaSp) Digital system design and implementation using discrete ICs and FPGAs; synchronous design of datapath and control units; state machine implementation methods; timing analysis; lab experiments, logic analyzers; schematic-entry and simulation; semester-end project. (Duplicates credit in former EE 102*L*). *Prerequisite:* EE 101.

202L Linear Circuits (4, FaSp) 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.

301 Introduction to Linear Systems (3, FaSp) Representation and analysis of linear time-invariant systems primarily for the continuous time case. Convolution, Fourier series and transform, Laplace transform, controls and communications applications. *Prerequisite:* EE 202*L*; *corequisite:* MATH 445.

320 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. *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.) *Corequisite:* ITP 411*x*.

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.

328Lx Circuits and Electronics for Computer Engineers (3, Fa) Introduction to the physical principles of governing analog circuits for data conversions and data communications. Elementary device behavior for digital systems. Not available for credit to electrical engineering majors. *Prerequisite:* PHYS 152*L*.

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. *Corequisite:* EE 338.

357 Basic Organization of Computer Systems (3, FaSp) 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 201*L*, 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, Fa) 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 and MATH 445.

415 Introduction to MEMS (3) (Enroll in AME 455)

434L Digital Signal Processing Design Laboratory (4) 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; *recommended preparation:* EE 469.

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; poly-phase 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.

445 Introduction to Robotics (4) (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*.

448L Communication Electronics (4, FaSp) Analysis, design, and experimental evaluation of transistor-level communication circuits and micro-systems. Transmission lines, impedance matching, noise, distortion, tuned amplifiers, mixers, oscillators, phase-locked loops. *Prerequisite:* EE 348*L*.

450 Introduction to Computer Networks (3, FaSpSm) 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 System Design Using Microprocessors (4, FaSp) Operation and timing of 8/16/32-bit microprocessors; asynchronous and synchronous SRAM interface; burst and pipelined bus cycles, parallel and serial I/O, interrupt controller, DMA controller, bus protocols. *Prerequisite:* EE 201*L* and EE 357; *recommended preparation:* EE 457*x*.

455x Introduction to Programming Systems Design (4) (Enroll in CSCI 455*x*)

457x Computer Systems Organization (3, FaSpSm) Register transfer level machine organization; MPIS instruction set architecture; performance; computer arithmetic; organization and detailed implementation of non-pipelined and pipelined processors; cache and virtual memory. Not available for graduate credit to computer science majors. *Prerequisite:* EE 357.

459L Embedded Systems Design Laboratory (3, Sp) Specification, design, implementation, testing and documentation of a digital system project using embedded processors, programmable logic; analog I/O interfaces and application specific hardware. *Prerequisite:* EE 454*L*.

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 and MATH 445.

465 Probabilistic Methods in Computer Systems Modeling (3, FaSp) 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.

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 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, Fa) Electric dipole transitions; traveling wave and resonant amplifiers; laser pumping and rate equations; threshold, frequency, and power output of lasers; holography; laser communication systems. *Corequisite:* EE 470.

473L Lasers and Optics Laboratory (3, Sp) 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.

474 Introduction to Photonics (3, Sp) Photonic system requirements; waveguide modes and dispersion; optical fiber modes, loss and dispersion; principles of operation of lasers, optical amplifiers, detectors and modulators; noise. *Prerequisite:* EE 330, EE 338.

475 Wireless Communication Technology (3, Fa) Fundamentals of wireless communication from a device point of view. Lab experiments and design project. *Recommended preparation:* EE 241, EE 483

476 Chemical Engineering Materials (3, Sp) (Enroll in CHE 476)

477L MOS VLSI Circuit Design (4, FaSp) 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 328*Lx* 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*.

479 Analog and Non-Linear Integrated Circuit Design (3, Fa) Analysis and design techniques for CMOS analog and non-linear integrated circuits. Frequency and noise characteristics of broadband amplifiers. Feedback, oscillators, and phase-locked loops. *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 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.

484 Communication System Design (3, Sp) Design and analysis of analog and digital communication systems. System models, requirements, development, performance analysis and component selection techniques. Comprehensive system design project. *Prerequisite:* EE 364, EE 475; *recommended preparation:* EE 467.

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 577a.

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)

509 Electromagnetics for Semiconductor Photonics (3) Overview of electromagnetics needed to understand and design photonic devices. Includes discussion of waveguides and resonant cavities and an introduction to photonic crystals.

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.

517 Statistics for Engineers (3, Sp) Presents statistics with engineering emphasis. Topics include confidence intervals, hypothesis testing, estimation, regression, nonparametric tests, analysis of variance, quality control, and experimental design. *Recommended preparation:* EE 464 or other probability course.

518 Semiconductor Materials for Devices (3) (Enroll in MASC 518)

519 Speech Recognition and Processing for Multimedia (3, Fa) 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.

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 psycho-acoustics. Algorithms for real-time implementation of immersive audio systems for integrated media applications. *Prerequisite:* EE 301; *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.

532 Wireless Internet and Pervasive Computing (3, Fa) Wireless Internet access technologies, 3G cellular systems, WAP and PKI protocols, mobile computing devices, network security for mobile E-commerce, software and middleware for pervasive, cluster, grid, and Internet computing. *Prerequisite:* EE 450; *recommended preparation:* EE 457x.

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 536. *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, Fa) The mobile communication channel; techniques used to combat the channel; cellular communications; multiple-access techniques; example mobile communication systems. *Recommended preparation:* EE 567.

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 Modern Solid-State Devices (3, Fa) Integrated-circuit technologies for mixed-signal communication and data systems. Constituent device models and their limitations. Contemporary research topics. *Prerequisites:* EE 338.

538 Spread Spectrum Systems (3, Sp) Covers the description analysis and design of Spread Spectrum Systems in military, navigation and wireless communication applications: portable, mobile, cellular and microcellular (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.

541 Radio Frequency Filter Design (3, Fa) Theory and realization of passive and transconductance-based active filters for radio frequency communications. Distributed and quasi-distributed passive filters. Circuit testing via scattering parameters. *Prerequisite:* EE 348.

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) *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*.

544 Radio Frequency Systems and Hardware (3, Sp) Elements of radio frequency communication systems: modulation/demodulation strategies, transmission-channel impairments, performance criteria, hardware (low-noise amplifiers, mixers, oscillators), digital back-end, contemporary case studies. *Prerequisite:* EE 301, EE 348*L*, EE 364.

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 AME 548)

549 Queueing Theory for Performance Modeling (3, Sp) 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 or EE 465.

550 Design and Analysis of Computer Communication Networks (3, Fa) 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, Irregular) 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*.

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, FaSp) 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*.

558 Optical Fiber Communication Systems (3, FaSp) 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, Sp) Distribution free classification, discriminant functions, training algorithms; statistical classification, parametric and non-parametric techniques, potential functions; non-supervised learning. *Prerequisite:* EE 464; *corequisite:* EE 441.

560 Digital System Design-Tools and Techniques (3, Sm) 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*x*, EE 454*L*; *recommended preparation:* familiarity with CAD tools.

561 Foundations of Artificial Intelligence (3-3, FaSp) (Enroll in CSCI 561)

562ab Random Processes in Engineering (a: 3, FaSpSm; b: 3, Irregular) *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) Elementary statistical design theory with applications to the design of digital communications receivers and radar receivers; signal design in digital communications. *Prerequisite:* EE 562*a*.

565ab Information Theory (a: 3, Fa; b: 3, Irregular) 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 441 and EE 464.

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, FaSp; b: 3, FaSp) *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 477; *b*: VLSI design project; chip level design issues: power and clock distribution, packaging, I/O; design techniques; testability; chip fabrication and test.

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 Wireless and Mobile Networks Design and Laboratory (3, Sp) Mobile ad hoc networks: ad hoc and geographic routing, resource discovery, medium access control, IP-mobility, mobility modeling, wired-wireless networks. Lab: wireless LAN measurement, mobile-IP, ad hoc routing. *Prerequisite:* CSCI 551 or EE 550 or EE 555; *recommended preparation:* programming, network simulation.

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*.

583 Adaptive Signal Processing (3, Sp) 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. *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 562a.

589 Statistical Optics (3) 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 562a.

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.

591 Magnetic Resonance Imaging and Reconstruction (3, Sp) Principles of magnetic resonance imaging. Spin physics, Fourier-based acquisition and reconstruction, generation of tissue contrast, fast imaging, artifact correction, advanced image reconstruction. *Prerequisite:* EE 483, familiarity with MATLAB; *recommended preparation:* EE 441, EE 464, BME 525.

592 Computational Methods for Biomedical Imaging (3, Sp) Analytic tomographic reconstruction from projections in 2-D and 3-D; algorithms for model based reconstruction; maximum likelihood and Bayesian methods; applications to CT, PET and MRI. *Prerequisite:* EE 483, EE 562a.

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:* EE 441, EE 464.

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 570a.

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.

607 Microelectromechanical Systems (3, FaSp) Exploration of the technology methods and physical principles of MEMS, and survey various MEMS of current interest. *Prerequisite:* EE 504.

608L Microelectromechanical Systems Laboratory (3, Fa) Lab fabrication and analysis of several MEMS applications, including diaphragm-based sensors and actuators, microfluidic components, and deformable mirror array.

619 Advanced Topics in Automatic Speech Recognition (3, Sp) Advanced topics in automatic speech recognition, speaker recognition, spoken dialogue, conversational multimedia interfaces. *Recommended preparation:* EE 464, EE 519, CSCI 544.

630 Advanced Electrical Circuit Theory (3) Systematic formulation of electrical network theory leading to generalized analysis methods. Multiport networks and electrical adjoints for sensitivity Analysis. 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 550 or EE 555 or CSCI 551.

652 Wireless Sensor Networks (3, Fa) Sensor network applications, design and analysis. Deployment; energy-efficiency; wireless communications; data-centric operation; capacity and lifetime; collaborative signal processing; reliability, fault-tolerance and security. *Prerequisite:* EE 450; *recommended preparation:* EE 465, good programming/mathematical skills.

653 Advanced Topics in Microarchitecture (3) Current research topics related to microprocessor architecture. Dynamically/statically scheduled processors, multithreading, chip multiprocessors, systems on a chip. Power, performance, complexity, dependability issues. Impact of technology. *Prerequisite:* EE 557.

657 Parallel and Distributed Computing (3, FaSpSm) Parallel programming models/software tools, multiprocessor systems, multicomputer clusters, latency tolerance, multithreading, fast message passing/middleware, interconnection networks, SMP, cluster, and grid computing applications. *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, Sp) 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. *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, Irregular) Synchronization in digital communication systems, tracking loop theory, acquisition and tracking, carrier and suppressed carrier waveforms, other advanced topics in communication theory. *Prerequisite*: EE 564.

666 Data Communication (3, Irregular) Receiver design for modulations and channels with memory. Iterative and adaptive detection and decoding algorithms. Application to fading, intersymbol interference, and interference limited channels. *Prerequisite:* EE 564; *recommended preparation:* EE 568, EE 563 or EE 583.

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 Multimedia Data Compression (3, Sp) Lossless compression, audio/speech coding, vector quantization, fractal compression, JPEG and JPEG-2000, video compression techniques and MPEG standards, video transmission over wired and wireless networks. *Recommended preparation:* EE 464.

674ab Advanced Topics in Computer Vision (3-3, Irregular) (Enroll in CSCI 674*ab*)

675 Engineering Approaches to Music Perception and Cognition (3, Sp) (Enroll in ISE 575)

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.

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@usc.edu

Director: L. Carter Wellford, Ph.D.

Associate Director: Massoud Pirbazari, Ph.D.

Faculty
Professors: Joseph Devinny, Ph.D. *(Civil Engineering);* Ronald C. Henry, Ph.D. *(Civil Engineering);* Jiin-Jen Lee, Ph.D., P.E. *(Civil Engineering)*;* Massoud Pirbazari, Ph.D. *(Civil Engineering);* Constantinos Sioutas, Sc.D. *(Civil Engineering);* Teh Fu Yen, Ph.D. *(Civil Engineering)*

*Recipient of university-wide or school teaching award.

Degree Requirements
Educational Program Objectives
The undergraduate programs in Environmental 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, or to continue their graduate studies in engineering, or to enter related areas such as 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 Environmental Engineering
See listing on page 554, Civil Engineering.

B.S., Civil Engineering/M.S., Civil Engineering
See Accelerated Dual Degrees in the Civil Engineering section, page 555.

Minor in Environmental Engineering
A minor in environmental engineering provides students 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. Students will learn how to control water pollution, maintain air quality, treat and properly dispose of wastes, and remediate sites contaminated due to improper disposal of hazardous waste. This minor also enhances students' employment opportunities in the field of environmental engineering. The program provides the necessary infrastructure for the pursuit of graduate studies in environmental engineering.

The minor in environmental engineering is offered to undergraduates in various fields of engineering and natural sciences.

Prerequisite courses
CHEM 105aLbL or CHEM 115aLbL; MATH 125, MATH 126 and MATH 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 428	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 553.

Master of Science in Environmental Engineering
See listing under Civil Engineering on page 556.

Master of Engineering in Environmental Quality Management
See listing under Civil Engineering on page 556.

Ph.D. in Engineering (Environmental Engineering)
See listing under Civil Engineering on page 557.

Graduate Certificate in Environmental Sciences, Policy and Engineering Sustainable Cities
See the listing under Sustainable Cities Program on page 611.

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, Fa)
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 AME 309.) *Prerequisite:* MATH 245.

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. Senior standing. *Prerequisite:* ENE 428; CE 309 or ENE 410.

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 Design of Solid and Hazardous Waste Engineering Systems (3, Sp) Engineering design of solid and hazardous waste facilities such as waste minimization, secured landfill, and hazardous waste treatment. *Prerequisite:* ENE 400, CE 473.

487 Environmental Biotechnology and Bioremediation (3, Sp) Understanding and designing microbiological processes for environmental protection; learning how processes in environmental biotechnology work; emerging applications for bioremediation of hazardous chemicals in the environment. *Prerequisite:* CE 210*L*, BISC 320*L*.

495 Seminars in Environmental Engineering (1, FaSp) Hazardous waste management, biodegradation of environmental pollutants, groundwater problems, waste minimization, energy resources, and air pollution control.

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.

510 Water Quality Management and Practice (3, Fa) Surface and ground water quality and resources management; water pollution in aquatic environment; water/wastewater infrastructure systems and management. Departmental approval.

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)

518 Environmental Systems Engineering and Management (3, Fa) Evaluating, implementing and managing effective environmental systems to prevent pollution, conserve energy and resources, reduce risks and achieve sustainability in business and industries.

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.

535 Applied Air Quality Management (3, Fa) Pollutant sampling; occupational, community, and personal exposures; receptor modeling; data analysis; health effects of air pollutants. Departmental approval.

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)

580 Applied Environmental Engineering Biotechnology (3, Sp) Fundamentals of bioremediation processes; bioremediation technologies for decontamination of air, water, and soil; global applications of bioremediation techniques. Departmental approval.

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.

Daniel J. Epstein Department of Industrial and Systems Engineering

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Chair: James E. Moore II, Ph.D.

Associate Chair: F. Stan Settles, Ph.D. *(Astronautics)*

Faculty
Daniel J. Epstein Chair: Sheldon M. Ross, Ph.D.

IBM Chair in Engineering Management: F. Stan Settles, Ph.D. *(Astronautics)*

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

TRW Professorship in Software Engineering: Barry Boehm, Ph.D. *(Computer Science)*

Professors: Barry Boehm, Ph.D. *(Computer Science);* Maged Dessouky, Ph.D.*; Randolph Hall, Ph.D.; Behrokh Khoshnevis, Ph.D.; James E. Moore II, Ph.D. *(Civil Engineering, Policy, Planning, and Development)*

Associate Professors: Najmedin Meshkati, Ph.D. *(Civil Engineering)*; Mansour Rahimi, Ph.D.

Assistant Professors: Elaine Chew, Ph.D.; Fernando Ordoñez, Ph.D.; Maria Yang, Ph.D.

Adjunct Professors: George Friedman, Ph.D.; Michael Mann, Ph.D.

Adjunct Associate Professor: Geza P. Bottlik, Engineer

Research Professors: Yigal Arens, Ph.D.; Malcolm Currie, Ph.D.; Mohamed I. Dessouky, Ph.D.; Peter Will, Ph.D.

Senior Lecturer: Kurt Palmer, Ph.D.*

Emeritus Professors: Clinton J. Ancker, Jr., Ph.D., P.E.; Gerald A. Fleischer, Ph.D., P.E.; Antranig V. Gafarian, Ph.D., P.E.; Homer H. Grant, M.S.; Ralph Keeney, Ph.D. *(Information and Operations Management);* Gerald Nadler, Ph.D., P.E.; Eberhardt Rechtin, Ph.D. *(Electrical Engineering/Systems)*

*Recipient of university-wide or school teaching award.

Honor 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 Kurt Palmer, Senior Lecturer, (213) 740-5960.

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, Professor, (213) 740-4891.

Degree Requirements

Educational Program Objectives
Industrial and Systems Engineering provides an education that blends information technology, engineering and management, with a strong emphasis on people skills, problem-solving skills and communication skills. Our objective is to prepare students for successful careers by teaching students to:

(1) Describe the essential components and inter-connective relationships within complex systems.

(2) Design and execute experiments and create mathematical, numerical, heuristic and other objective models.

(3) Understand the innovations that form the building blocks of the modern technological world.

(4) Generate and validate solutions to a problem.

(5) Work with others in a collaborative environment and contribute to the success of an organization.

(6) Clearly articulate and communicate findings.

(7) Understand contemporary developments in the field.

(8) Describe the principles for managing and operating production systems within their area of emphasis.

For additional information, visit our web site at *www.usc.edu/dept/ise.*

Bachelor of Science in Industrial and Systems Engineering
The minimum requirement for the degree is 128 units. A GPA of C (2.0) or higher is required in all upper division courses in the Epstein Department of Industrial and Systems Engineering, including any approved substitutes for these courses taken at USC. See the common requirements for undergraduate degrees, page 518.

COMPOSITION/WRITING REQUIREMENT		7 UNITS
WRIT 140	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION	20 UNITS

Category III is fulfilled by PHYS/CHEM requirement.

PRE-MAJOR REQUIREMENTS		UNITS
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Linear Differential Equations	4
MATH 226	Calculus III	4
Physics Requirements		
PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Chemistry Elective		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
Economics Requirement		
ECON 203	Principles of Microeconomics	4

MAJOR REQUIREMENTS		UNITS
Business		
ACCT 410x	Accounting for Non-Business Majors	4
Engineering		
ENGR 102ab	Engineering Freshman Academy	1-1
Electrical Engineering		
AME 341a	Mechnoptonics Laboratory I, or	3
EE 326L*	Essentials of Electrical Engineering	4
Computer Science		
CSCI 101	Fundamentals of Computer Programming	3
ISE 382	Introduction to Computer Systems, or	
CSCI 485	File and Database Management	3
Industrial and Systems Engineering		
ISE 105	Introduction to Industrial and Systems Engineering	2
ISE 220	Probability Concepts in Engineering	3
ISE 225	Engineering Statistics I	3
ISE 232L	Manufacturing Processes	3
ISE 310L	Production I: Facilities and Logistics	4
ISE 330	Introduction to Operations Research I	3
ISE 331	Introduction to Operations Research II	3
ISE 370L	Human Factors in Work Design	4
ISE 410	Production II: Planning, Scheduling and Control	3
ISE 426	Statistical Quality Control	3
ISE 435	Discrete Systems Simulation	3
ISE 440	Work, Technology, and Organization	3
ISE 460	Engineering Economy	3
ISE 495abx	Senior Design Project	2-2

Major Electives

Approved engineering electives*	3
Free electives	7
Total units required for the program	128

* Students selecting EE 326 are only required to complete 2 units of approved engineering elective.

Bachelor of Science in Industrial and Systems Engineering (Information Systems Engineering)

The minimum requirement for the degree is 128 units. A GPA of C (2.0) or higher is required in all upper division courses in the Epstein Department of Industrial and Systems Engineering, including any approved substitutes for these courses taken at USC. Students must choose either the computer science track or the information and operations management track. See the common requirements for undergraduate degrees, page 518.

During the freshman year, students in either track enroll in a common set of required courses. By the sophomore year, students enroll in required and elective courses for one track or the other.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 140	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION	20 UNITS

Category III is fulfilled by PHYS/CHEM requirement.

PRE-MAJOR REQUIREMENTS		UNITS

Math Requirement

MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 225	Linear Algebra and Linear Differential Equations	4

Physics Requirements

PHYS 151	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152	Fundamentals of Physics II: Electricity and Magnetism	4

Chemistry Elective

CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4

Engineering course

ENGR 102ab	Engineering Freshman Academy	1-1

COMPUTER SCIENCE TRACK		UNITS

Computer Science courses

CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	4
CSCI 201L	Principles of Software Development	4

Industrial and Systems Engineering courses

ISE 105	Introduction to Industrial and Systems Engineering	2
ISE 220	Probability Concepts in Engineering	3
ISE 225	Engineering Statistics I	3
ISE 310L	Production I: Facilities and Logistics	4
ISE 330	Introduction to Operations Research: Deterministic Models	3
ISE 382	Introduction to Computer Systems	3
ISE 410	Production II: Planning and Scheduling	3
ISE 435	Discrete Systems Simulation	3
ISE 440	Work, Technology, and Organization	3
ISE 460	Engineering Economy	3
ISE 470	Human/Computer Interface Design	3
ISE 495abx	Senior Design Project	2-2

Electives*

Computer Science/Information Technology Program electives	10
Approved engineering electives	3
Free electives	10

INFORMATION AND OPERATIONS MANAGEMENT TRACK		UNITS

Business courses

IOM 431	Business Information Systems	4
IOM 433	Business Information Systems Analysis and Design	4
IOM 435	Business Database Systems	4

Computer Science course

CSCI 101L	Fundamentals of Computer Programming	3

Industrial and Systems Engineering courses

ISE 105	Introduction to Industrial and Systems Engineering	2
ISE 220	Probability Concepts in Engineering	3
ISE 225	Engineering Statistics I	3
ISE 310L	Production I: Facilities and Logistics	4

ISE 330	Introduction to Operations Research: Deterministic Models	3
ISE 382	Introduction to Computer Systems	3
ISE 410	Production II: Planning and Scheduling	3
ISE 435	Discrete Systems Simulation	3
ISE 440	Work, Technology, and Organization	3
ISE 460	Engineering Economy	3
ISE 470	Human/Computer Interface Design	3
ISE 495abx	Senior Design Project	2-2

Electives*

Computer Science/Information Technology program electives	6
Approved engineering electives	3
Free electives	10
Total units required for the program	128

* Electives in the CSCI/ITP or approved engineering electives lists are geared so that students can take courses in an area of interest. Courses not listed may be petitioned for approval through the department.

CSCI/ITP Electives: CSCI 271, CSCI 303, CSCI 351, CSCI 460, CSCI 477L, CSCI 480, CSCI 485, EE 357, EE 450, EE 457, ITP 109x, ITP 150x, ITP 165x, ITP 203x, ITP 211x, ITP 215x, ITP 250x, ITP 321x

Approved Engineering Electives: Any of the courses listed below that are not specifically required in a student's program may be selected to satisfy the approved engineering elective requirement. Substitutions of a graduate level ISE course will be considered upon petition.

AME 341a, AME 341B, CE 408, CE 460, CE 471, ISE 331, ISE 426, ISE 470.

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
BUAD 301	Technical Entrepreneurship	3
ISE 330	Introduction to Operations Research: Deterministic Models	3
ISE 370L	Human Factors in Work Design	4
ISE 440	Work, Technology, and Organization	3
ISE 460	Engineering Economy	3

Accelerated Dual Degree Program
The accelerated dual degree program offers qualified students the opportunity to simultaneously complete the requirements for the B.S. and M.S. degrees in five years. Students are eligible for the accelerated dual degree program upon completing 96 or more units toward their B.S. with a GPA of 3.2 or higher. Qualified students who are interested should see their advisor in their junior year to begin planning for the inclusion of graduate courses during their senior year. Students should apply to the graduate program in the fall of their senior year. Eligible students will be automatically accepted to the M.S. program without needing to take the GRE. All requirements for both the B.S. and M.S. degrees must be met; however, up to six units of course work will be counted toward

satisfying the unit requirements of both programs. Application information may be obtained in the Viterbi School of Engineering Office of Admissions and Student Affairs. Students should see their departmental advisors for assistance with course selection.

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 Viterbi School of Engineering. This program enhances the technical capabilities of the industrial engineer. The degree requires 30 units.

The M.S. program is for students who want to become technical leaders in the field of industrial and systems engineering. Applicants to the program are expected to have a bachelor's degree in an engineering discipline with undergraduate course work in computing, probability and statistics, and engineering economy. Admitted students who do not meet prerequisites will be assigned courses to complete the deficiencies.

A total of 30 units is required for the degree, of which at least 18 units must be completed in the Industrial and Systems Engineering Department. Of the 30 units, 20 must be at the 500 level or above.

REQUIRED COURSES		UNITS
ISE 514	Advanced Production Planning and Scheduling	3
ISE 515	Engineering Project Management	3

ISE ELECTIVES (CHOOSE ONE FROM EACH GROUP)		UNITS
Systems Design		
ISE 525	Design of Experiments	3
ISE 527	Quality Management for Engineers	3
ISE 541	Systems Engineering Theory and Practice	3
Production		
ISE 511L	Computer Aided Manufacturing	3
ISE 513	Inventory Systems	3
ISE 517	Modern Enterprise Systems	3
Systems Performance		
ISE 544	Management of Engineering Teams	3
ISE 564	Performance Analysis	3
ISE 570	Human Factors in Engineering	3

Information Systems		
ISE 580	Advanced Concepts in Computer Simulation	3
ISE 582	Web Technology for Industrial Engineering	3
Quantitative Methods		
ISE 532	Network Flows	3
ISE 536	Linear Programming and Extensions	3
ISE 538	Elements of Stochastic Processes	3
Advisor approved electives		9
Total units:		30

Master of Science in Product Development Engineering
See the listing under Product Development Engineering, page 610.

Master of Science in Systems Architecture and Engineering
See the listing under Systems Architecture and Engineering, page 612.

Master of Science in System Safety and Security
This interdisciplinary program educates students in modeling risks and consequences of random events and the development of strategies to improve system safety and system security. The program is available via distance education.

Applicants to the program are expected to have a degree in engineering, science of equivalent with undergraduate work in engineering economy and statistics. Admitted students who do not meet the course work requirements will be assigned courses to complete the deficiencies.

A total of 29 units is required for the degree. Eighteen units must be at the 500 level or above.

REQUIRED COURSES		UNITS
ISE 550	Engineering Management of Government-Funded Programs	3
ISE 561	Economic Analysis of Engineering Projects	3
ISE 562	Value and Decision Theory	3
PPD 501	Public Sector Economics	4
PPD 587	Risk Analysis	4
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Select 3 courses from one concentration (9 units):

Cyber-Security:
Available on the Distance Education Network (DEN). Concentration requires undergraduate degree in computer science or equivalent.

CSCI 530	Security Systems	4
CSCI 551	Computer Communications	3
CSCI 555	Advanced Operating Systems	3
CSCI 556	Introduction to Cryptography	3
CSCI 558L	Internetworking and Distributed Systems Laboratory	3
CSCI 577a	Software Engineering	4
CSCI 578	Software Architectures	3

Environmental Security:
Concentration requires undergraduate degree in environmental engineering or equivalent.

CE 513L	Instrumental Methods for Environmental Analysis	3
CE 523	Physical Processes of Environmental Engineering	3
CE 554	Risk and Reliability Analysis for Civil Infrastructure Systems	3
ENE 510	Water Quality Management and Practice	3
ENE 516	Hazardous Waste Management	3
ENE 518	Environmental Systems Engineering and Management	3
ENE 535	Applied Air Quality Management	3
ENE 580	Applied Environmental Engineering Biotechnology	3

Critical Infrastructure:

CE 465	Water Supply and Sewerage System Design	3
CE 554	Risk and Reliability Analysis for Civil Infrastructure Systems	3
CE 560	Simulation of Civil Infrastructure Systems Performance	3
CE 583	Design of Transportation Facilities	3
CE 589	Port Engineering: Planning and Operations	3
EE 510	Symmetrical Components	3
EE 516	Electric Power Distribution	3
EE 525	Power System Protection	3
EE 550	Design and Analysis of Computer Communication Networks	3

Policy and Planning:

PPD 541	Public Financial Management and Budgeting	4
PPD 542	Policy and Program Evaluation	4
PPD 554	Public Policy Formulation	4
PPD 555	Public Policy Formulation and Implementation	4

Structural Safety:
Concentration requires undergraduate degree in civil engineering or equivalent.

CE 480	Structural Systems Design	3
CE 529a	Finite Element Analysis	3
CE 536	Structural Design for Dynamic Loads	3
CE 541a	Dynamics of Structures	3
CE 554	Risk and Reliability Analysis for Civil Infrastructure Systems	3
CE 555	Underwater Structures	3
CE 560	Simulation of Civil Infrastructure Systems Performances	3

Systems:
Available on DEN.

ISE 525	Design of Experiments	3
ISE 541	Systems Engineering Theory and Practice	3
ISE 542	Advanced Topics in Systems Engineering	3
ISE 544	Management of Engineering Teams	3
SAE 549	Systems Architecting	3
Elective		3

An elective is selected with approval of advisor to reach minimum unit requirement for graduation

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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 or GSBA 506ab Applied Managerial Statistics and GSBA 504 Operations Management or 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 CSCI 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. Dual degree students may not count courses taken outside the Marshall School of Business toward the 48 units.

Viterbi School of Engineering

REQUIRED COURSES	(MINIMUM 18 UNITS)	
ISE 514	Advanced Production Planning and Scheduling	3
ISE 515	Engineering Project Management	3
ISE 561	Economic Analysis of Engineering Projects	3
ISE 564	Performance Analysis	3
ISE 580	Advanced Concepts in Computer Simulation	3
Elective	Chosen with advisor approval	3
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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) 740-4893

Program Director: F. Stan Settles, Ph.D.

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. A total of 18 units must be at the 500 level or above.

Applicants to the program are expected to have a degree in engineering or the equivalent with undergraduate course work in engineering economy. Admitted students who do not meet the course work requirements will be assigned courses to complete the deficiencies.

At least one course from each of the seven areas listed below is required:

Accounting (3 units):

| GSBA 510 | Accounting Concepts and Financial Reporting |
| GSBA 518 | Accounting Control Systems |

Projects and Teams (3 units):

| ISE 515 | Engineering Project Management |
| ISE 544 | Management of Engineering Teams |

Technology (3 units):

ISE 545	Technology Development and Implementation
ISE 555	Invention and Technology Development
ISE 585	Strategic Management of Technology

Information Systems (3 units):

IOM 535	Database Management
ISE 582	Web Technology for Industrial Engineering
ISE 583	Enterprise Wide Information Systems

Engineering Economy (3 units):

| ISE 561 | Economic Analysis of Engineering Projects |
| ISE 562 | Value and Decision Theory |

Enterprises (3 units):

ISE 517	Modern Enterprise Systems
ISE 527	Quality Management for Engineers
ISE 550	Engineering Management of Government-Funded Programs
ISE 564	Performance Analysis

Quantitative Methods (3 units):

ISE 513	Inventory Systems
ISE 514	Advanced Production Planning and Scheduling
ISE 525	Design of Experiments
ISE 530	Introduction to Operations Research
ISE 580	Advanced Concepts in Computer Simulation

Electives (9 units):

Three courses or 9 units of electives are chosen from specialization tracks with consent of the advisor, including:

- Construction Project Management
- Entrepreneurship
- Information Systems
- Manufacturing
- Software Engineering
- Systems Engineering

Master of Science in Operations Research Engineering

Ethel Percy Andrus
Gerontology Center 240
(213) 740-4891
FAX: (213) 740-1120
isedept@usc.edu

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 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	3
ISE 582	Web Technology for Industrial Engineering	3

Select at least two of the following six courses:

ISE 513	Inventory Systems (3)	
ISE 514	Advanced Production Planning and Scheduling (3)	
ISE 520	Optimization: Theory and Algorithms (3)	
ISE 525	Design of Experiments (3)	
ISE 541	Systems Engineering Theory and Practice (3)	
ISE 562	Value and Decision Theory (3)	6
400- or 500-level computer science course, approved by faculty advisor		3
Two electives, approved by faculty advisor		6
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Graduate Certificate in System Safety and Security

This abbreviated interdisciplinary program educates students in modeling risks and consequences of random events, and the development of strategies to improve system safety and system security. The requirements include the core courses of the master's degree in system safety and security, but do not permit electives of specialization. The program is available via distance education.

Applicants to the program are expected to have a degree in engineering, science or the equivalent with undergraduate course work in engineering economy and statistics. Admitted students who do not meet the course work requirements will be assigned courses to complete the deficiencies.

A total of 17 units is required for the certificate.

REQUIRED COURSES		UNITS
ISE 550	Engineering Management of Government-Funded Programs	3
ISE 561	Economic Analysis of Engineering Projects	3
ISE 562	Value and Decision Theory	3
PPD 501	Public Sector Economics	4
PPD 587	Risk Analysis	4
		17

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*.

105 Introduction to Industrial and Systems Engineering (2, FaSp) 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.

220 Probability Concepts in Engineering (3, Fa) 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, Sp) 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. *Recommended preparation:* 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; *corequisite:* ISE 460.

330 Introduction to Operations Research: Deterministic Models (3, Fa) Introduction to linear programming; transportation and assignment problems; dynamic programming; integer programming; nonlinear programming. *Prerequisite:* MATH 225.

331 Introduction to Operations Research: Stochastic Models (3, Sp) Stochastic processes; Markov chains; queueing theory and queueing decision models; probabilistic inventory models. *Prerequisite:* ISE 220; *recommended preparation*: 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. *Corequisite:* ISE 330.

415 Industrial Automation (3, Irr) 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, Fa) 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. Upper division standing.

460 Engineering Economy (3, FaSpSm) Utilizing principles of economic analysis for choice of engineering alternatives and engineering systems. Pre-tax and after-tax economy studies. Upper division standing.

470 Human/Computer Interface Design (3, Sp) Essentials of human factors and computer interface for the design, development, implementation, and evaluation of integrated media systems.

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

495abx Senior Design Project (2-2 FaSp) *a:* Preparation and development of the senior project proposal. Not available for graduate credit. Senior standing in industrial and systems engineering. Open only to industrial and systems engineering students. *Corequisite:* ISE 225, ISE 310; ISE 382 or CSCI 485. *b:* Group work on an industrial engineering design problem in an organization. Not available for graduate credit. Senior standing in industrial and systems engineering. *Corequisite:* ISE 370 or ISE 470; ISE 435.

498x Foundations of Industrial and Systems Engineering (4, Irr) 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, Fa) 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, FaSm) 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, FaSpSm) 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) 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 Modern Enterprise Systems (3, FaSp) Study of various aspects of integrated manufacturing and service 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, Fa) 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 Design of Experiments (3, FaSp) Planning data collection to investigate relationships between product/process design choices (materials, temperatures, etc.) and performance, empirical modeling to predict performance, identification of the best design choices. *Recommended preparation:* ISE 225.

527 Quality Management for Engineers (3, FaSp) Principles of quality management, quality philosophies and frameworks, quality leadership and strategic planning, process management, and performance measurements.

528 Advanced Statistical Aspects of Engineering Reliability (3) Advanced statistical methods applied to reliability engineering. Experimental design analysis and interpretation of multifactor reliability problems.

530 Introduction to Operations Research (3, Sp) 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) 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, Fa) 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.

541 Systems Engineering Theory and Practice (3, FaSpSm) 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.

542 Advanced Topics in Systems Engineering (3, FaSp) Advanced topics in integration software management and systems engineering, probabilistic foundations of decision-based theory, quantitative risk management, decision-based design, and safety aspects of systems engineering. *Prerequisite:* ISE 541.

544 Management of Engineering Teams (3, FaSp) 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, Fa) Principles and practices of technology development and implementation, with application to products and systems in manufacturing and services. Graded CR/NC.

549 Systems Architecting (3, FaSp) (Enroll in SAE 549)

550 Engineering Management of Government-Funded Programs (3, Sp) Analysis of risks inherent in managing high-tech/high-cost government-funded engineering programs; tools and techniques for coping with the impacts of politically-driven budgets on the engineering design process. *Recommended preparation:* two years of work experience.

555 Invention and Technology Development (3, Sp) This project-oriented course elaborates on the process of engaging creative thought, tools and techniques for invention, and issues involved in bringing inventions to the production phase. Graded CR/NC.

561 Economic Analysis of Engineering Projects (3, FaSp) 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, Irr) 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.

571 Human Factors Issues in Integrated Media Systems (3) Psychological, cognitive, physical and social characteristics of human factors and how they affect information technology design, development and evaluation for Integrated Media Systems.

573 Work Physiology (3) Survey of metabolic processes in the performance of physical work, study of individual and environmental factors affecting these processes.

575 Engineering Approaches to Music Perception and Cognition (3, Sp) Survey of computational research in music perception and cognition. Topics include: induction of pitch and time structures, pattern and style recognition, expression synthesis, analysis and interpretation. Open to students with graduate standing in engineering. *Recommended preparation:* Programming experience (C/C++ or Java)

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 Web Technology for Industrial Engineering (3, Fa) A fast-paced, project-based introduction to designing and implementing interactive Web applications. Emphasizes skills for building engineering and market research applications requiring information gathering, analysis, representation. *Prerequisite:* ISE 382.

583 Enterprise Wide Information Systems (3, FaSp) The role of enterprise resource planning systems (ERPs) in an organization and the task of implementing and managing the IS function.

585 Strategic Management of Technology (3, FaSp) Management skills and tools for technology intensive enterprises. Life cycle analysis of technology from planning through exploitation, obsolescence and renewal.

589 Port Engineering: Planning and Operations (3, Sp) (Enroll in CE 589)

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
www.itp.usc.edu

Director: Anthony Borquez, Ed.D.

Instructors: Patrick Dent, M.S.; Nitin Kale, M.S.; Tim Langdell, Ph.D.; Ashish Soni; Richard Vawter, M.S.; Justin Verduyn, B.S.; Richard Wainess, M.S.

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.

Minor in 3-D Animation
The 3-D animation minor merges theoretical concepts and practical skills to prepare students for a career in their major field of work with incorporation of 3-D animation and interactive technologies. Through integration of three major disciplines (cinema, fine arts and information technology), students gain a solid foundation in a wide range of important industry and academic skills. Two concentrations are available depending on professional goals and career or industry objectives.

Student should meet the regular admission standards and have a declared USC major. Students will complete an application for the minor with the Viterbi School of Engineering. School of Engineering, School of Fine Arts and School of Cinema-Television students must get departmental approval to participate in this minor. To be approved for the minor, students must have: completed a minimum of 30 units of college level courses, attained a minimum GPA of 3.0, and achieved basic computer literacy. Along with the Viterbi School of Engineering application, students will submit a one-page personal statement, describing their professional goals and how this minor will support those goals. For specific information on admission and application procedures, contact the Information Technology Program at (213) 740-4542.

Requirements for completion (core courses plus one concentration)
Minimum units: 29-31 (depending on concentration)

CORE COURSES (19 UNITS)		UNITS
CTAN 330	Animation Fundamentals	2
CTAN 451	History of Animation	2
CTAN 452	Introduction to Computer Animation	2
FA 101a	Drawing	4
FA 102	Design Fundamentals	4

ITP 215x	3-D Modeling, Animation, Compositing, and Special Effects	2
ITP 414x*	Seminar and Portfolio Development	3

* ITP 414x may be taken after a minimum of 20 units of minor course work have been completed.

TRADITIONAL 3-D ANIMATION CONCENTRATION (12 UNITS)		UNITS
FA 106	Sculpture I	4
ITP 305x	Advanced 3-D Modeling, Animation, Compositing, and Special Effects	3
ITP 315x	Applications for 3-D Special Effects and Character Animation	2
ITP 360x	3-D Industry Tools	3

INTERACTIVE 3-D ANIMATION CONCENTRATION (10-11 UNITS)		UNITS
CTAN 450a	Animation Theory and Techniques	2
ITP 211x	Multimedia Authoring	2
ITP 330x	Interactive 3-D Environments	3
Choose one		
FA 436	Art and Technology	4
ITP 411x	Interactive Multimedia Production	3

Minor in Law and Internet Technology

Students in this minor will understand the ongoing legal battles with Internet file sharers, the legal aspects of computer and network security, and how cyber crime and other technical mideeds are brought to justice.

Requirements for completion (core course plus one elective)
Minimum units: 20

REQUIRED COURSES		UNITS
ITP 260x	Internet Technologies	4
ITP 477x	Security and Computer Forensics	4
LAW 200x	Law and Society	4
LAW 450x	Internet Law	4

ELECTIVE (CHOOSE ONE)		UNITS
ITP 457x	Network Security	4
LAW 343	Courts and Society	4

Minor in Video Game Design and Management

The video game design minor integrates theoretical concepts and practical skills to prepare students for a career in interactive entertainment, specifically the video game industry. Through integration of two major disciplines (cinema and information technology), students will be exposed to a variety of design concepts related to creating video games including: level design, game-play control, user interface, multiplayer, game mechanics, and storytelling. As opposed to the video game programming minor where students will be writing code and programming game engines, students in the video game design and management minor will apply design concepts to different game genres and use game design software tools to create a working demo of a video game during the course of the minor program.

Students should meet the regular admissions standards and have a declared USC major. Students will complete an application for the minor with the Viterbi School of Engineering. For specific information on admission and application procedures, contact the Information Technology Program at (213) 740-4542.

Requirements for completion (core courses plus one elective)
Minimum units: 22

CORE COURSES (20 UNITS)		
CTIN 483	Programming for Interactivity	4
CTIN 488*	Game Design Workshop	4
CTIN 489*	Intermediate Game Design Workshop	4
ITP 280x	Video Game Production	4
ITP 391x	Designing and Producing Video Games	4

ELECTIVE COURSES (2-4 UNITS - CHOOSE ONE)		
CTAN 432	Introduction to Animation	2
CTAN 452	Introduction to Computer Animation	2
CTIN 309	Introduction to Interactive Entertainment	4
CTIN 482	Designing Online Multiplayer Game Environments	4
CTIN 491	Advanced Game Project	4
ITP 414x**	Advanced Project Development	3
ITP 491x	Level Design and Development for Video Games	4

*Prerequisite is CTIN 483

**ITP 414*x* may be taken after a minimum of 20 units of minor course work have been completed.

Minor in Video Game Programming

The video game programming minor integrates the theoretical concepts and practical skills to prepare students for a career in interactive entertainment, specifically the video game industry. Through integration of two major disciplines (computer science and information technology), students will be exposed to a variety of programming concepts related to creating video games including: 3-D graphics, artificial intelligence, particle systems, rendering, collision detection, game algorithms, physics concepts, and math formulas. In contrast to the video game design minor where the focus is applying design concepts and using software design tools, students in the video game programming minor will evaluate, write and debug code, in addition to creating a game engine during the course of the minor.

Students should meet the regular admissions standards and have a declared USC major. Students will complete an application for the minor with the Viterbi School of Engineering. For specific information on admission and application procedures, contact the Information Technology Program at (213) 740-4542.

Requirements for completion (core courses plus electives)
Minimum units: 27

CORE COURSES (19 UNITS)		
CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	4
ITP 280	Video Game Production	4
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4

ELECTIVE COURSES (8 UNITS - 4 UNITS MUST BE ITP)		
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 480	Computer Graphics	3
ITP 382	Mobile Game Programming	4
ITP 461*	Artificial Intelligence in Video Games	1
ITP 481**	Video Game Graphics	1
ITP 484	Multiplayer Game Programming	4

*ITP 461 requires concurrent enrollment with CSCI 460.

**ITP 481 requires concurrent enrollment with CSCI 480.

Minor in Web Technologies and Applications

The Web technologies and applications minor combines both theoretical concepts and practical skills to prepare students for a career in their major field of work while incorporating the Web. Students will be able to design, develop and apply major Web technologies and advancements. The broad areas of study will be client-side and server-side programming, databases, multimedia and project-based Web development. Electives are available depending on the students' academic and professional goals.

Students should meet the regular admissions standards and have a declared USC major.

Requirements for Completion
Minimum units: 25

REQUIRED COURSES (20 UNITS)		UNITS
CSCI 455x	Introduction to Programming Systems Design	4
ITP 104x	Internet Publishing Technologies	2
ITP 204x	Fundamentals of Web Development	4
ITP 300x	Database Web Development	3
ITP 411x	Interactive Multimedia Production	3
ITP 460x	Web Application Project	4

ELECTIVES (TWO COURSES)		UNITS
ITP 109x	Introduction to Java Programming	2
ITP 325x	Web Security	3
ITP 404x	Intermediate Web Development	3
ITP 420x	Structuring Data for the Web	3
ITP 450x	Designing eCommerce Applications	4

Courses of Instruction

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. 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.

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.

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.

104x Internet Publishing Technologies (2, FaSp) Basic Internet publishing using HTML and other Web technologies. Concepts and theory of Web publishing and production. Introduction to page layout and design. *Prerequisite:* basic computer literacy.

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, FaSpSm) Introduction to object-oriented software design for business problems. Creation of console applications, windowed applications, and interactive Web applets.

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.

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.

204x Fundamentals of Web Development 4, FaSp) Programming fundamentals necessary for Web development. Scripting languages, development tools and techniques for creating interactive, dynamic Web pages. *Prerequisite:* ITP 104*x*.

209x Object Oriented Programming Using Java (3, FaSp) Basic object-oriented concepts and object-oriented analysis and design as they relate to Java technology. Object-oriented programming for developing applications with Java technology. *Prerequisite:* ITP 109*x*.

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* .

211x Multimedia Authoring (2, FaSpSm)
Introduction to interactive multimedia programming; integrated audio, graphics, video, and animation for interactive multimedia; object oriented programming, web, CD-ROM, and hybrid applications. *Recommended preparation:* programming experience.

212x Digital Media Design and Management (3, FaSpSm) Design and composition as it applies to digital media, including web, CD, interactivity, and motion graphics. Media management, client relations, project and asset management.

215x 3-D Modeling, Animation, Compositing and Special Effects (2, FaSpSm)
Overview of developing a 3-D 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 2-D paint, drawing or CAD program.

216x Web Animation and Interactivity (2, FaSpSm) 2-D vector graphics for web and animation. Scripting techniques for interactivity. Action Script syntax, logic and control. *Recommended preparation:* basic computer knowledge.

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.

260x Internet Technologies (4, FaSp)
Overview of emerging technologies on the Internet including multimedia components, networking, security tools, web-based databases, and wireless 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*.

280x Video Game Production (4, FaSpSm)
History of video games; overview of game genres; phases of video game development (concept, preproduction, production, post-production); roles of artists, programmers, designers, and producers.

300x Database Web Development (3, FaSp)
Fundamental theory and technologies for creating dynamic, database-driven Web sites: Structured Query Language. *Prerequisite:* ITP 104*x; recommended preparation:* ITP 204*x*.

305x Advanced 3-D Modeling, Animation and Special Effects (3, FaSpSm) Advanced modeling, surfacing, and animation techniques, as well as compositing, dynamics, scripting, and other advanced 3-D automation procedures. *Prerequisite:* ITP 215*x* or ARCH 207*a*.

309x Developing Enterprise Applications Using Java (3, FaSp) Java architecture and key logic for business components; Servlets, Server Pages and Enterprise Java Beans technologies, to design and construct secure and scalable n-tier applications.

315x Applications for 3-D Special Effects and Character Animation (2) This advanced 3-D 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.

322Lx Enterprise Resource Planning (2)
An Enterprise Resource Planning system is configured for a company from the ground up. Emphasis is placed on cross-functional business processes and critical integration points. *Prerequisite:* ITP 320*x*.

325x Web Security (3, FaSp) Computer networks and inherent security issues that apply to networking. Encryption protocols, securing servers, and secure network architectures. *Prerequisite:* ITP 104*x*.

330x Interactive 3-D Environments (3, FaSpSm) Introduces techniques to design and develop interactive, multi-user 3-D, 2-D, and textual environments, for business, personal communications, education, and gaming for the web and CD. *Prerequisite:* ITP 211*x*.

345x Video Game Art and Animation (3, FaSp) Create art and modeling for video games. Model, texture, light, and animate a sequence to be used in a video game engine. *Prerequisite:* ITP 215*x*.

360x 3-D Industry Tools (3, FaSp) Techniques, concepts and tools for professional 3-D animation development. Strengths/weaknesses of industry-standard middle-end and high-end animation packages; hands-on instruction, discussion, and analysis. *Prerequisite:* ITP 215*x* or ARCH 207*a*.

377x Linux System Administration (3, FaSp) Installation, customization and administration of Linux in a networked environment. *Prerequisite:* ITP 225*x*.

380x Video Game Programming (4, FaSpSm) Underlying concepts and principles required for programming video games (topics include vectors, transformations, 3-D math, geometric primitives, matrices). *Prerequisite:* CSCI 102*L* or ITP 165*x*.

382x Mobile Game Programming (4, FaSp) Programming methodologies for writing mobile game applications for handheld devices, including the following programming considerations for embedded systems: graphics, screen size, memory, programming interfaces. *Recommended preparation:* previous programming experience.

391x Designing and Producing Video Games (4, FaSp) Key elements for designing effective video games and the processes involved in early development; roles of producer and manager, marketing and sales, and considerations pertaining to licensing and franchises. *Prerequisite:* ITP 280*x*.

404x Intermediate Web Development (3, Fa) Web development using server-side technologies, including scripting, CGI, active server pages and Java servlets. *Prerequisite:* ITP 204*x*.

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.

414x Advanced Project Development (3, FaSp) Advanced planning, budgeting, and production processes and techniques for new media projects; team-building and management practices for creative teams. Graded CR/NC. *Recommended preparation:* a minimum 20 units from the ITP 3-D Animation minor.

420x Structuring Data for the Web (3, FaSp) Building web applications focused on content in web documents; develop XML document using DTD, DOM, XSL; facilitate data interchange between Web sites. *Prerequisite:* ITP 300*x*.

440x Enterprise Data Management (3, FaSp) Advanced concepts in database management; design, customization, maintenance and management of a database in an enterprise environment. *Prerequisite:* IOM 435 or ITP 300.

450x Designing eCommerce Applications (4, FaSp) Fundamentals of business and technological elements of electronic commerce. Design of solutions for the Internet using eCommerce development technologies and programming Business-to-Consumer applications. *Prerequisite:* ITP 404*x* or ITP 413*x*.

451x Designing Business-to-Business E-Commerce Solutions (3, FaSp) Foundations of b2b electronic marketplaces; automation of sell-side/buy-side e-commerce through XML programming and catalogue interfacing; implementation of b2b commerce between existing enterprise resource planning systems. *Prerequisite:* ITP 204*x* or ITP 450*x*; *recommended preparation:* ITP 320*x*.

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 320*x*; *corequisite:* ACCT 454.

455Lx Enterprise Information Portals (3, Sp) Enterprise Information Portals for various case companies will be explored. Student will design, install, configure and administer core functionalities of a basic portal solution. *Prerequisite:* ITP 320*x*.

457x Network Security (4) Network policy and mechanism, firewalls, malicious code; intrusion detection, prevention, response; cryptographic protocols for privacy; risks of misuse, cost of prevention, and societal issues. *Prerequisite:* ITP 104*x* or ITP 260*x*.

460x Web Application Project (4, FaSp) Analysis, planning, creation and maintenance of a web application are undertaken, using principles and practices of system development methodology. *Prerequisite:* ITP 404*x*.

461x Artificial Intelligence in Video Games (1, FaSp) Concepts and programming techniques for building artificial intelligence into video games. Games AI topics include: finite state machines, pathfinding, A-Life and flocking, and genetics. *Prerequisite:* CSCI 102*L*; *corequisite:* CSCI 460.

477x Security and Computer Forensics (4, FaSp) Prevention, detection, apprehension, and prosecution of security violators and cyber criminals; techniques for tracking attackers accross the Internet and gaining forensic information from computer systems. *Prerequisite:* ITP 104 or ITP 265.

481x Video Game Graphics (1, FaSp) Practical approach to understanding the methods and programming techniques used in real-time graphics, data structures and algorithms in games, rendering techniques, and particle systems. *Prerequisite:* CSCI 102*L*; *corequisite:* CSCI 480.

484x Multiplayer Game Programming (4, FaSp) Designing, building, and programming a fully functional multiplayer game with online or network capabilities, a platform-independent network library and back-end database. *Prerequisite:* CSCI 102*L* or ITP 165*x*.

485x Programming Game Engines (4, FaSp) Techniques for building the core components of a game engine; 2-D/3-D graphics, collision detection, artificial intelligence algorithms, shading, programming input devices. *Prerequisite:* CSCI 102*L* or ITP 165*x*.

491x Level Design and Development for Video Games (4, FaSp) Theories and practices of defining, prototyping, testing, and refining a video game level, development of game level documents, and the tools for managing the development process. *Prerequisite:* ITP 391*x*.

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
Gerontology Center 240
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FAX: (213) 740-1120
Email: isedept@usc.edu

Program Director: B. Khoshnevis, Ph.D.

Master of Science in Manufacturing Engineering

Manufacturing engineering at USC is a multi-disciplinary 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
CSCI 585	Database Systems, or	
EE 450	Introduction to	
	Computer Networks	3
ISE 511L	Computer Aided	
	Manufacturing	3
ISE 517	Modern Enterprise	
	Systems	3
ISE 525	Design of Experiments, or	
AME 525	Engineering Analysis	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
www.usc.edu/dept/materials_science

Chair: Florian Mansfeld, Ph.D.

Faculty
M.C. Gill Chair in Composite Materials: Steven R. Nutt, Ph.D. *(Aerospace and Mechanical Engineering)*

Kenneth T. Norris Professorship in Engineering: Anupam Madhukar, Ph.D. *(Physics)*

Professors: P. Daniel Dapkus, Ph.D. *(Electrical Engineering);* Martin Gundersen, Ph.D. *(Electrical Engineering);* Rajiv K. Kalia, Ph.D. *(Physics and Computer Science);* Bruce Koel, Ph.D. *(Chemistry);* Terence G. Langdon, Ph.D., D.Sc. *(Aerospace and Mechanical Engineering and Earth Sciences);* Anupam Madhukar, Ph.D. *(Physics);* Florian Mansfeld, Ph.D. *(Chemical Engineering);* Steven R. Nutt,

Ph.D. *(Aerospace and Mechanical Engineering);* Charles G. Sammis, Ph.D. *(Earth Sciences)*;* Armand R. Tanguay, Jr., Ph.D. *(Electrical Engineering, Biomedical Engineering);* Mark E. Thompson, Ph.D. *(Chemistry);* Priya Vashishta, Ph.D. *(Physics, Computer Science and Biomedical Engineering)*

Associate Professors: Edward Goo, Ph.D.; Aiichiro Nakano, Ph.D. *(Computer Science, Physics and Biomedical Engineering);* Ching-An Peng, Ph.D. *(Chemical Engineering)*

Adjunct Associate Professor: Daniel H. Rich, Ph.D.

Adjunct Assistant Professor: David Zhou, Ph.D.

Research Professor: Peter Will, Ph.D. *(Information Sciences Institute)*

Research Assistant Professor: Atul Konkar, Ph.D.

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);* Ronald Salovey, Ph.D. *(Chemical 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 the 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 Viterbi 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
CHE 476	Chemical Engineering Materials, or	
CE 334L	Mechanical Behavior of Materials	3
MASC 310	Materials Behavior and Processing	3
MASC 440	Materials and the Environment	3
Advisor approved electives	(minimum) 4	
		16

ELECTIVES		UNITS
BME 410	Introduction to Biomaterials and Tissue Engineering	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: EE 471; MASC 501, MASC 503, MASC 504, MASC 505 and MASC 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 Viterbi School of Engineering. Students may elect to work for this degree in either the Materials Science or Aerospace and 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.

334L Mechanical Behavior of Materials (3) (Enroll in CE 334*L*)

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)

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 471.

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.

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).

535L Transmission Electron Microscopy (4)
Transmission electron microscopy and techniques. Specimen-electron beam interaction, electron diffraction and image formation. X-ray microanalysis. Laboratory involves hands-on training on the transmission electron microscope. (Duplicates credit in former MASC 536*L*.) *Recommended preparation:* MASC 505.

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 AME 559)

560 Fatigue and Fracture (3) (Enroll in AME 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.

575 Basics of Atomistic Simulation of Materials (3, Fa) Building a parallel computer from components; molecular dynamics method; computation of structural, thermodynamics and transport properties; simulation projects. *Prerequisite:* Undergraduate course in thermodynamics or statistical physics; *recommended preparation:* Fortran, Unix/Linux.

583 Materials Selection (3) (Enroll in AME 588)

584 Fracture Mechanics and Mechanisms (3) (Enroll in AME 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. Graded CR/NC.

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 Super-lattices (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.

Multimedia and Creative Technologies

Bachelor of Science in Electrical Engineering (Integrated Media Systems)
See listing under Electrical Engineering page 578.

Minor in Interactive Multimedia
A minor in interactive multimedia is open to undergraduate students in all majors. This minor provides students with the skills and knowledge necessary to apply and develop interactive multimedia tools within a variety of industries. Although this program is geared towards the non-technical student, computer literacy is a key component to being successful in this program.

Students must apply to the program through the Viterbi School of Engineering, and approval of the student's advisor will be required on the application form. Students are required to complete a minimum of 19 units of course work consisting of both core requirements and elective courses.

Successful completion of the interactive multimedia minor requires a minimum of a 2.0 GPA in the following courses.

CORE COURSES		UNITS
CTIN 309	Introduction to Interactive Media	4
EE 320x	Digital Media Basics for Multimedia	3
ITP 101x	Introduction to Information Technology, or	4
ITP 105x*	Introduction to Computer Technologies and Applications	2

ITP 210x	Multimedia Applications for Windows (corequisite to EE 320)	2
JOUR 413	Introduction to Online Journalism	4
Total core units:		13-15

*May be waived based on demonstrated computer literacy.

Elective Courses: 6-8 units
Students will choose two elective courses from the following list:

Cinema-TV
CTIN 483	Programming for Interactivity	4
CTIN 488	Game Design Workshop	4

Engineering
EE 450	Introduction to Computer Networks	3
ITP 413x	Interactive Web Development, or	4
CSCI 351*	Programming and Multimedia on the World Wide Web	3

*Prerequisites waived if students are competent in programming.

Journalism
JOUR 417	Online Journalism Management	2

Fine Arts (Multimedia Design)
FA 302	Design II	4
FA 310	Digital Photo Studio	4
FA 410	Advanced Digital Photo Studio	4
FA 436	Art and Technology	4

Total units required for completion of minor: 19-23 units

Total units including all prerequisite courses: 26-36

Minor in Multimedia and Creative Technologies
A minor in multimedia and creative technologies is available to undergraduate students majoring in electrical engineering, computer engineering/computer science and computer science and to other students who have sufficient background for the required courses and elective courses. This minor provides students with the skills necessary to compete in the multimedia industry.

Students must apply to the Viterbi School of Engineering for the minor and departmental approval will be required. At least 16 units must be taken outside of the major department. Students must have completed at least one semester of USC course work and be in good academic standing. Students must take at least 16 units, which are unique to the minor (i.e., not required to fulfill the major, another minor or general education requirement). Other specific university guidelines apply to minors and can be found in the Academic Policies section.

REQUIRED COURSES		UNITS
CSCI 351	Programming and Multimedia on the World Wide Web	3
CTPR 405	Filmic Expression	4
EE 321	Introduction to Integrated Media Systems, or	
EE 469	Introduction to Digital Media Engineering	3
ITP 411x	Interactive Multimedia Production (corequisite to EE 321)	3
Total core units:		13

ADVISOR APPROVED ELECTIVES (6 UNITS)		UNITS

Choose one course from the following:

EE 450	Introduction to Computer Networks, or	3
CSCI 480	Computer Graphics	3

and at least one course from the following:

CTAN 452	Introduction to Computer Animation	2
CTIN 483	Programming for Interactivity	4
FA 310	Digital Photo Studio	4
FA 410	Advanced Digital Photo Studio	4
FA 436	Art and Technology	4
MUEA 474abx	Electronic Synthesizer Techniques	2-4, 2-4

Total units required for completion of the minor: 19

Total units including all prerequisite courses: 38-49

Master of Science in Computer Science (Multimedia and Creative Technologies)

Students may earn a specialization in multimedia and creative technologies by completing the general requirements for the Master of Science in Computer Science and the following additional courses:

Every student must complete CSCI 576 Multimedia Systems Design (3). Students must also complete at least two courses selected from one of the two specialization tracks: Graphics and Vision or Networks and Databases.

GRAPHICS AND VISION TRACK		UNITS
CSCI 480	Computer Graphics	3
CSCI 574	Computer Vision	3
CSCI 580	3-D Graphics and Rendering	3
CSCI 582	Geometric Modeling	3
CSCI 674	Advanced Topics in Computer Vision	3
EE 569	Introduction to Digital Image Processing	3

NETWORKS AND DATABASES TRACK		UNITS
CSCI 485	File and Database Management	3
CSCI 551	Computer Communications	3
CSCI 558L	Internetworking and Distributed Systems Laboratory	3
CSCI 585*	Database Systems	3
CSCI 586	Database Systems Interoperability	3
CSCI 694ab	Topics in Computer Networks and Distributed Systems	3-3
EE 450	Introduction to Computer Networks	3

Suggested Core and Elective Courses
Since this specialization is systems oriented, it is recommended (but not required) that students select CSCI 555 Advanced Operating Systems and EE 557 Computer Systems Architecture as two of their three core courses. Additional electives may be taken from the two tracks or from the partial list of suggestions below.

CSCI 561*	Foundations of Artificial Intelligence	3
CSCI 573	Advanced Artificial Intelligence	3
CSCI 577ab*	Software Engineering	4-4
CSCI 583	Computational Geometry	3
CSCI 588	Specification and Design of User Interface Software	3
CSCI 590	Directed Research	max 6
EE 554	Real Time Computer Systems	3
ITP 411x	Interactive Multimedia Production	3

*Also satisfies a core course requirement in the general requirements for the M.S. degree in Computer Science.

Master of Science in Integrated Media Systems

The Master of Science in Integrated Media Systems is an interdisciplinary degree offered by the Computer Science and Electrical Engineering Departments. It is available to students who satisfy the following admission requirements: (a) B.S. degree in Computer Science, Computer Engineering or Electrical Engineering; or (b) a bachelor's degree in another area of engineering or science or mathematics; however, the student must have the equivalent of USC course CSCI 455 and may be required to take additional prerequisite courses for entry into this program; (c) undergraduate cumulative GPA of 3.0 or above; and (d) satisfactory general GRE scores of at least 400 verbal, 650 quantitative and 550 analytical.

Students can enter this program in fall or spring semesters, and it is available to full-time and part-time students.

Deficiency courses, e.g., CSCI 455, cannot be counted toward the 27 units and must be taken if needed.

1. The M.S. in Integrated Media Systems requires a minimum of 27 units. It is a course-work-based program, although students can choose to take up to six units of directed research.

2. ITP 411x Interactive Multimedia Production is a required course.

3. The field of integrated media systems has been broken into four areas of specialization: media processing and hardware design, graphics and visualization, interconnection networks, and multimedia information management. Each area has one 400- or 500-entry level course associated with it (noted by asterisk). The student must take two of the four entry level courses (only one from each area). The student must take the 400-level course, unless he or she already has had an equivalent course. If the student uses the 400-level course as the entry course, the 500-level course may be taken later in the program. The entry level courses will provide the student with some breadth across the field.

4. The remaining 18 units can only be taken from an approved list of IMS courses that will be updated annually.

5. The student must take two 3-unit area courses in *both* of the two areas of specialization within which the student has already taken the two entry-level courses. These courses must be from the approved list of courses. Doing this will provide the student with some depth as well as breadth. If the student takes the 400-level entry-level course to satisfy requirement (3), she or he may take the 500-level entry level course to satisfy requirement (5).

6. The remaining six units can be chosen by the student. Some possibilities are:
• Directed Research (3-6 units): useful for the student's "portfolio."
• If the student has only taken 6 units of 400-level courses, she or he could take one of the other two entry-level courses and a 500-level course from that area of specialization. Doing this will provide the student with even greater breadth.
• Six more units either in one or from both areas of specialization, thereby gaining even greater depth.
• A mixture of directed research and six additional units in one or both areas of specialization.

7. A maximum of nine units can be taken at the 400-level.

8. EE 477L can count toward the 27 units only if students do not need CSCI 480 or EE 450 or CSCI 485 to be counted as an entry-level course. Otherwise, EE 477L must be treated as a deficiency course and cannot be counted toward the 27 units.

9. For students who choose the Interconnection Networks area of specialization and need to take both CSCI 402 and EE 450, one of them must be treated as a deficiency course and cannot be counted toward the 27 units.

Approved Courses for the M.S. in Integrated Media Systems (four areas of specialization)

MEDIA PROCESSING AND HARDWARE DESIGN		UNITS
EE 469*	Introduction to Digital Media Engineering	3
EE 477L	MOS VLSI Circuit Design	4
EE 483*	Introduction to Digital Signal Processing	3
EE 519	Speech Recognition and Processing for Multimedia	3
EE 522	Immersive Audio Signal Processing	3
EE 560	Digital System Design: Tools and Techniques	3
EE 569	Introduction to Digital Image Processing	3
EE 577a	VLSI System Design	3
EE 586L	Advanced DSP Design Laboratory	4
EE 590	Directed Research	1-6
EE 596	Wavelets	3
EE 669	Multimedia Data Compression	3

*Students interested in digital signal processing courses should take EE 483 as their entry level course rather than EE 469.

GRAPHICS AND VISUALIZATION		UNITS
CSCI 480*	Computer Graphics	3
CSCI 574	Computer Vision	3
CSCI 576	Multimedia Systems Design	3
CSCI 580*	3D Graphics and Rendering	3
CSCI 582	Geometric Modeling	3
CSCI 588	Specification and Design of User Interface Software	3
CSCI 590	Directed Research	1-6
EE 569	Introduction to Digital Image Processing	3

INTERCONNECTION NETWORKS		UNITS
CSCI 402x	Operating Systems	3
CSCI 551*	Computer Communications	3
CSCI 558L	Internetworking and Distributed Systems Laboratory	3
CSCI 590	Directed Research	1-6
EE 450*	Introduction to Computer Networks	3
EE 555	Broadband Network Architectures	3
EE 590	Directed Research	1-6

MULTIMEDIA INFORMATION MANAGEMENT		UNITS
CSCI 485*	File and Database Management	3
CSCI 555	Advanced Operating Systems	3
CSCI 561	Foundations of Artificial Intelligence	3
CSCI 570	Analysis of Algorithms	3
CSCI 573	Advanced Artificial Intelligence	3
CSCI 577ab	Software Engineering	4-4
CSCI 585*	Database Systems	3
CSCI 586	Database Systems Interoperability	3
CSCI 590	Directed Research	1-6

*Entry level course

Master of Science in Electrical Engineering (Multimedia and Creative Technologies)
Students may earn a specialization in multimedia and creative technologies by completing the general requirements for the Master of Science in Electrical Engineering and the following additional requirements:

(1) At most four units of electives can be taken outside of the Viterbi School of Engineering *with advisor approval.* Some examples are CTAN 452 Introduction to Computer Animation (2 units) and CTIN 483 Programming for Interactivity (4 units).

(2) Computer science courses that are cross-listed with EE can (but do not have to) count toward the 18 EE units. Up to nine units of other CSCI courses that either are or are not cross-listed can also be used. Multimedia and creative technologies draws heavily on concepts and techniques from computer science.

(3) Students must include the following four courses in their program

CSCI 576	Multimedia Systems Design	3
EE 483	Introduction to Digital Signal Processing, or	
EE 469	Introduction to Digital Media Engineering	3
EE 519	Speech Recognition and Processing for Multimedia, or	
EE 522	Immersive Audio Signal Processing	3
EE 569	Introduction to Digital Image Processing	3

A course can be waived if a student can demonstrate equivalent knowledge of the material and if the course instructor will certify it.

(4) Students can only take courses from the list of approved courses, except *with advisor approval* students may include in their program one multimedia-related EE 599 or CSCI 599 Special Topics course (2-4 units). Every course requires prior approval from the faculty advisor, recorded each semester on the plan of study form.

(5) Students may include a maximum of six units of EE 590 Directed Research in their programs. Before registering for these units, the faculty advisor must approve a written description of the intended multimedia research project signed by the faculty member who will supervise the student.

(6) Students entering this program are expected to have already completed, either at USC or at another institution, formal course work equivalent to USC course EE 364 Introduction to Probability and Statistics for Electrical Engineering. Although a course on probability is not required, it is *recommended preparation* for some of the courses such as EE 569.

(7) Although not required, students should be proficient in C or C++ programming, at the level taught in CSCI 455x.

(8) Although not required, ITP 411x Integrated Multimedia Production (3 units) will provide the student with hands-on experience in using multimedia application tools. This will help the student prepare a portfolio, which is expected by industry from students who major in a multimedia program.

(9) The remaining units *must* be chosen from the following list of courses.

Approved Courses for the Multimedia Specialization

COURSE IN BIOMEDICAL ENGINEERING		UNITS
BME 527	Integration of Medical Imaging Systems	3

COURSES IN ELECTRICAL ENGINEERING		UNITS
EE 450	Introduction to Computer Networks	3
EE 455x	Introduction to Programming Systems Design	3
EE 519	Speech Recognition and Processing for Multimedia	3
EE 522	Immersive Audio Signal Processing	3
EE 532	Wireless Internet and Pervasive Computing	3
EE 555	Broadband Network Architectures	3
EE 586L	Advanced DSP Design Laboratory	4
EE 590	Directed Research	1-6
EE 596	Wavelets	3
EE 599	Special Topics	3
EE 669	Multimedia Data Compression	3

COURSES IN COMPUTER SCIENCE		UNITS
CSCI 480	Computer Graphics	3
CSCI 485	File and Database Management	3
CSCI 520	Computer Animation and Simulation	3
CSCI 551	Computer Communications	3
CSCI 558L	Internetwork and Distributed Systems Laboratory	3
CSCI 571	Web Technologies	3
CSCI 574	Computer Vision	3
CSCI 580	3D Graphics and Rendering	3
CSCI 582	Geometric Modeling	3
CSCI 585	Database Systems	3
CSCI 599	Special Topics	2-4

COURSES FROM THE SCHOOL OF CINEMA-TELEVISION		UNITS
CTAN 452	Introduction to Computer Animation	2
CTIN 483	Programming for Interactivity	4

COURSE IN HUMAN FACTORS		UNITS
ISE 571	Human Factors Issues in Integrated Media Systems	3

COURSE IN INFORMATION TECHNOLOGY		UNITS
ITP 411x	Interactive Multimedia Production	3

Petroleum Engineering

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Director: Iraj Ershaghi, Ph.D., P.E.

Faculty
Zohrab A. Kaprielian Dean's Chair in Engineering: Yannis C. Yortsos, Ph.D. *(Chemical Engineering)*

Omar B. Milligan Chair in Petroleum Engineering: Iraj Ershaghi, Ph.D., P.E. *(Chemical Engineering)*

Professor: George V. Chilingar, Ph.D. *(Civil Engineering)*

Lecturers: Alejandro Bugacov, Ph.D.; Robert Ehrlich, Ph.D.; Donald G. Hill, Ph.D.; Allan Spivak, Ph.D.; Jalal Torabzadeh, Ph.D.; Malvina Val Lerma, M.S.; Victor M. Ziegler, Ph.D.

Emeritus Professor: Elmer L. Dougherty, Ph.D. *(Chemical Engineering)*

Petroleum Engineering Honor Society: Pi Epsilon Tau

Degree Requirements

Bachelor of Science in Chemical Engineering (Petroleum Engineering)
See the listing under Chemical Engineering, page 547.

Bachelor of Science in Mechanical Engineering (Petroleum Engineering)
See the listing under Aerospace and Mechanical Engineering, page 528.

Minor in Petroleum Engineering
A minor in petroleum engineering consisting of 16 required units is available to undergraduate majors in various fields of engineering and applied science. Besides preparing for graduate study in petroleum engineering, the program will prepare students for careers in areas of national need such as the exploration, recovery and production of subterranean resources, and the underground disposal of hazardous wastes.

Prerequisite courses:
MATH 125, MATH 126, MATH 226, MATH 245, PHYS 151L and CHEM 105aL
CE 309

REQUIRED COURSES		UNITS
PTE 461	Formation Evaluation	3
PTE 462	Economic, Risk and Formation Productivity Analysis	4
PTE 463L	Introduction to Transport Processes in Porous Media	3
PTE 464L	Petroleum Reservoir Engineering	3
PTE 465L	Drilling Technology and Subsurface Methods	3

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Master of Science in Petroleum Engineering
The Master of Science in Petroleum Engineering is awarded in strict conformity with the general requirements of the Viterbi School of Engineering. A student may be permitted to elect the program without thesis upon approval from the department.

Master of Science in Petroleum Engineering/Smart Oilfield Technologies
The Master of Science in Petroleum Engineering/Smart Oilfield Technologies is awarded in strict conformity with the general requirements of the Viterbi School of Engineering. A student may be permitted to elect the program without thesis upon approval from the department. Course requirements are similar to the existing M.S. degree in Petroleum Engineering in terms of core requirements.

Certificate in Smart Oilfield Technologies
The Certificate in Smart Oilfield Techniques is designed for practicing engineers and scientists who enter petroleum engineering related fields and/or who wish to obtain training in the specific smart oilfields area. The applicants may enroll at USC as limited status students. They must apply and be admitted to the program before they complete 9 units of the required course work. The certificate program is open to applicants with an undergraduate degree in engineering or sciences who meet the admission criteria as limited students. The required courses consist of the following 12 units:

REQUIRED COURSES		UNITS
PTE 586	Intelligent and Collaborative Oilfield Systems Characterization and Management	3
PTE 587	Smart Completions, Oilfield Sensors and Sensor Technology	3
PTE 588	Smart Oilfield Data Mining	3
PTE 589	Advanced Oilfield Operations with Remote Visualization and Control	3

These classes will be available through the USC Distance Education Network (DEN). The credit for classes may be applied toward the M.S. or Ph.D. in Petroleum 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 program and must satisfy all normal admission requirements. All courses for the certificate must be taken at USC.

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

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

Courses of Instruction

PETROLEUM ENGINEERING (PTE)

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

202xg Energy and Society (4, Irregular)
Study of the impact of the development, production, and global distribution of energy on societal, political, and economic behavior. Not available for major credit to engineering majors. *Prerequisite:* pass Math Skill Level.

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

411x Introduction to Transport Processes in Porous Media (3, Fa) Properties of porous rocks; capillary effect, single phase and multiphase flow through porous media; diffusion and dispersion, miscible displacement, heat transfer. Lecture, 3 hours. Not available for credit to Petroleum Engineering majors. *Prerequisite:* MATH 245, CHEM 105*aL* or CHEM 115*aL*, PHYS 151*L*, CE 309.

412x Petroleum Reservoir Engineering (3, Fa) Properties of reservoir fluids, volumetric and material balances for gas and oil reservoirs; reservoir modeling concepts. Lecture, 3 hours. Not available for credit to Petroleum Engineering majors.

461 Formation Evaluation (3, Fa) Concepts of petroleum geology, interpretation of downhole surveys and measurements including well logs, MWD, mud logs and samples. *Corequisite:* PTE 463*L*.

462 Economic, Risk and Formation Productivity Analysis (4, Sp) Principle of economic evaluation, risk analysis, reserves estimation, decline curves, energy prices, and well transients for flow prediction. *Prerequisite:* PTE 461.

463L Introduction to Transport Processes in Porous Media (3, Fa) Properties of porous rocks; capillarity effect, single-phase and multiphase flow through porous media; diffusion and dispersion, miscible displacement, heat transfer. Lecture, 3 hours; laboratory, 3 hours. *Prerequisite:* MATH 245, CHEM 105*aL* or CHEM 115*aL*, PHYS 151*L*.

464L Petroleum Reservoir Engineering (3, Sp) Properties of reservoir fluids, volumetric and material balances for gas and oil reservoirs; reservoir modeling concepts. Lecture, 3 hours; laboratory, 3 hours. *Prerequisite:* PTE 463*L*.

465L Drilling Technology and Subsurface Methods (3, Fa) Theory and practice in drilling technology; mechanical properties of reservoir rocks; well completion; acidizing and fracturing, oil production technology. Lecture, 3 hours; laboratory, 3 hours. *Prerequisite:* PTE 464*L*.

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 petroleum engineering and related fields.

502 Applied Well Logging (3, Sp) Modern well logs from both open and cased holes, and methods for analyzing them to obtain information on reservoir rock properties and fluid saturations. *Corequisite:* PTE 506.

507 Engineering and Economic Evaluation of Subsurface Reservoirs (3, Fa) Studies, data and methods for estimating size of underground fluid deposits for predicting physical and economic behavior of designed flow schemes, and for quantifying uncertainty. *Prerequisite:* PTE 464*L*.

508 Numerical Simulation of Subsurface Flow and Transport Processes (3, Sp) Formulation and solution of the equations describing the underground flow of fluids through porous media. Includes mass (contaminant) transport in single and multiphase flow. *Prerequisite:* PTE 507 or graduate standing in engineering.

514 Drilling Engineering (2, 2 years, Fa) Rock mechanics; rotary drilling processes; bit selection; optimizing bit weight and rotational speed; well hydraulics and control; casing design and cementing; directional and offshore drilling.

517 Testing of Wells and Aquifers (3, Sp) Principles of well testing; down hole device; Aquifer tests; slug tests; DST; pressure transient modeling in homogeneous and heterogeneous systems; parameter estimation; computer aided techniques. *Prerequisite:* PTE 464*L*.

531 Enhanced Oil Recovery (3, 2 years, Sp) This course surveys current enhanced oil recovery processes, including water-flooding, miscible displacement, and thermal oil recovery. *Prerequisite:* PTE 507.

542 Carbonate Rocks (2, Irregular) Classification; porosity development; source rocks; wettability; capillary pressure curves; compressibility; surface areas; relative permeabilities; various petrophysical properties; formation evaluation; overpressures; thin section analysis.

545 Corrosion Control in Petroleum Production (2, Irregular) Types of corrosion encountered in petroleum production; methods for practical control including use of inhibitors, coatings, and cathodic protection. *Prerequisite:* CHEM 430*a*.

555 Well Completion, Stimulation, and Damage Control (3) This course reviews current practices related to well completion methods, wellbore stimulation, and damage control. Formation damage prevention and stimulation methods are emphasized. *Prerequisite:* graduate standing.

572 Engineering Geostatistics (2, Irregular) Use of geostatistical methods for exploration and development of mineral and petroleum resources, application of semivariogram, kriging, cokriging, nonlinear and parametric estimation and conditional stimulation. *Prerequisite:* graduate standing; knowledge of statistics or departmental approval.

578 Advanced Production Engineering (2, 2 years, Sp) Principles of oil well and gas well production; design of artificial lift systems and surface operations; field problems of enhanced oil recovery operations.

581 Environmental Technology in the Petroleum Industry (3, 2 years, Fa) This course examines engineering and scientific principles necessary for understanding, assessing, and remediating environmental problems in the petroleum industry including drilling, production, transportation and refining operations. *Prerequisite:* graduate standing.

582 Fluid Flow and Transport Processes in Porous Media (3, 2 years, Fa) Principles of single and multiphase flow through porous media; mechanisms of immiscible and miscible displacement; momentum, heat and mass transport in porous media.

586 Intelligent and Collaborative Oilfield Systems Characterization and Management (3, Fa) Review of soft computing methods such as neural networks, fuzzy logic, problematic reasoning in reservoir characterization, dynamic reservoir modeling, oilfield data integration and analysis of uncertainty in prediction. Limited to students with graduate standing. *Recommended preparation:* prerequisites for non-majors.

587 Smart Completions, Oilfield Sensors and Sensor Technology (3, Sp) Intelligent Wellbore completion, technology of subsurface and surface sensors, deployment and data acquisition, telemonitoring and feedback, reliability of sensors, data transmission, systems networks. *Recommended preparation:* prerequisites for non-majors.

588 Smart Oilfield Data Mining (3, Fa) Methods for oilfield data mining, data preparation mining images, prediction and knowledge discovery, subset selection, pattern recognition. Limited to students with graduate standing. *Recommended preparation:* prerequisites for non-majors.

589 Advanced Oilfield Operations with Remote Immersive Visualization and Control (3, Sp) Immersive subsurface and surface environments, web based monitoring and feedback, visualizing risk, unattended operation. Limited to students with graduate standing. *Recommended preparation:* prerequisites for non-majors.

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.

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

690 Directed Research (1-4) Laboratory study of specific problems for candidates for the degree engineer in petroleum 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.

Product Development Engineering

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Program Director: Stephen C-Y Lu, Ph.D.

Master of Science in Product Development Engineering
The Master of Science in Product Development Engineering (MSPED) is an inter-disciplinary graduate degree program at USC jointly offered by the Aerospace and Mechanical Engineering and the Daniel J. Epstein Industrial and Systems Engineering Departments. The Aerospace and Mechanical Engineering Department manages this joint degree program. Students can enter this program in either the fall or spring semesters, and it is available to full-time and part-time students.

Admission
The program has the following admission requirements:
- A bachelor's degree in an area of engineering or science;
- An undergraduate cumulative GPA of 3.0 or above; and
- Satisfactory general GRE scores of at least 400 verbal, 650 quantitative and 550 analytical.

The MSPED program requires a minimum of 27 units to complete. Although it is mainly a course work-based program, students can choose to complete the program with or without a thesis requirement. For the thesis option, 4 of the 27 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 from the AME and ISE departments. For the non-thesis option, 18 of the 27 units must be at the 500 level or higher from the AME and ISE departments, and/or closely related departments. As well, students can choose to take up to 6 units of directed research (e.g., AME 590 or ISE 590). Students must maintain a minimal cumulative GPA of 3.0 in USC course work to graduate.

The program's prerequisite is a minimum of one 400 level course in either engineering design or engineering economy. Admitted students who do not meet this prerequisite will be assigned appropriate USC course(s) to complete the deficiencies. Deficiency courses, if taken at the 400 level, may be counted toward 27 units as general electives with advisor approval.

Depending on the academic background and career interests of students, the program offers two areas of specialization, product development technology and product development systems. The product development technology specialization will prepare students for a career as future product development engineers, while the product development systems specialization will prepare students as future product development managers. Students entering this program must declare their choice of an area of specialization and follow the requirements of each area of specialization to graduate.

Curriculum
The required 27 units are grouped into four categories of courses for each area of specialization as follows:

REQUIRED COURSES (6 UNITS)		UNITS
AME 503	Advanced Mechanical Design	3
ISE 545	Technology Development and Implementation	3

PRODUCT DEVELOPMENT TECHNOLOGY

REQUIRED COURSES (6 UNITS)		UNITS
AME 505	Engineering Information Modeling	3
AME 525	Engineering Analysis, or	
AME 526	Engineering Analytical Methods	3

PRODUCT DEVELOPMENT TECHNOLOGY

TECHNICAL ELECTIVES (6 UNITS)		UNITS
AME 408	Computer-Aided Design of Mechanical Systems	3
AME 410	Engineering Design Theory and Methodology	3
AME 481	Aircraft Design	3
AME 501	Spacecraft System Design	3
AME 504	Metallurgical Design	3
AME 506	Design of Low Cost Space Missions	3
AME 527	Elements of Vehicle and Energy Systems Design	3
AME 528	Elements of Composite Structure Design	3
AME 544	Computer Control of Mechanical Systems	3
AME 556	Systems Architecture Design Series	3
AME 588	Materials Selection	3
CE 550	Computer-Aided Engineering	3
CE 551	Computer-Aided Engineering Project	3
SAE 549	Systems Architecting	3

PRODUCT DEVELOPMENT SYSTEMS

REQUIRED COURSES (6 UNITS)		UNITS
ISE 515	Engineering Project Management	3
ISE 555	Invention and Technology Development	3

PRODUCT DEVELOPMENT SYSTEMS

TECHNICAL ELECTIVES (6 UNITS)		UNITS
ISE 415	Industrial Automation	3
ISE 460	Engineering Economy	3
ISE 470	Human/Computer Interface Design	3
ISE 511L	Computer Aided Manufacturing	3
ISE 517	Modern Enterprise Systems	3
ISE 525	Design of Experiments	3
ISE 527	Quality Management for Engineers	3
ISE 528	Advanced Statistical Aspects of Engineering Reliability	3
ISE 541	Systems Engineering Theory and Practice	3
ISE 544	Management of Engineering Teams	3
ISE 561	Economic Analysis of Engineering Projects	3
ISE 580	Advanced Concepts in Computer Simulation	3
ISE 585	Strategic Management of Technology	3

GENERAL ELECTIVES (9 UNITS)	UNITS
Advisor-approved electives (Must be upper-division 400 or 500 level courses; up to 4 units can be transferred from other institutions)	

Total units required for degree	27

Sustainable Cities Program

Kaprielian Hall 413
(213) 821-1325
Email: wvuong@usc.edu
www.usc.edu/dept/geography/ESPE

Director: Jennifer Wolch (*Geography*)

Director of Academic Affairs: Joseph Devinny
(Environmental Engineering)

Graduate Certificate in Environmental Sciences, Policy and Engineering Sustainable Cities

The Sustainable Cities Program is a multi-disciplinary doctoral certificate program open to USC students pursuing Ph.D. programs in many disciplines including engineering, biology, chemistry, earth sciences, economics, geography, international relations, political science, sociology, urban planning and others.

Creating sustainable cities for the 21st century is a major challenge for society. The growth of cities, caused by natural population increase and massive rural-to-urban population flows, poses critical environmental problems that reach far beyond municipal boundaries and transcend national borders. Resolving such problems requires contributions from natural scientists, engineers, behavioral scientists and policy experts. To solve problems of national concern, such scientists must work productively with public administrators, political decision-makers and diverse interest groups. This program seeks to equip doctoral students with both the requisite knowledge of other fields and the political, interpersonal and communication skills necessary to succeed in practical contexts.

The Sustainable Cities Program is designed to be integrated into each student's departmentally based course of doctoral study, with each department determining how individual sustainable cities program courses can be used to meet doctoral program requirements.

Required Courses
Sixteen units of graduate work are required.

CORE COURSES (8 UNITS)		UNITS
CE 564	Methods for Assessment and Protection of Environmental Quality	3
COMM 646	Negotiating Boundaries in Environmental Research	2
GEOG 611	Sustainable Cities: Problems and Policies	3

Research (8 units)
Students complete 8 units of directed research in their home departments over the course of three semesters (2 units in semesters two and three of the program and 4 units in the fourth semester).

The first two directed research courses are devoted to an individual research project related to their dissertation, supervised by at least two faculty members from different fields.

The third directed research course is a semester-long collaborative project involving professors and students from at least three different disciplines.

Admission Requirements and Application Procedures
Students must be currently matriculated in a USC doctoral degree program or applicants for admission to this program. Students may obtain an admissions package from the USC Graduate School or their intended home department. To apply for admission students should send a letter by February 1 to William Vuong, Center for Sustainable Cities, University of Southern California, 3620 S. Vermont Ave., Los Angeles, CA 90089-0255. This letter should: (1) describe the student's field of interest and how it contributes to the study of urban sustainability; (2) identify potential collaborative projects in which the student might wish to participate; (3) provide contact information, including address, phone number, email address and the primary academic unit. Students already enrolled in a USC doctoral program who wish to apply to the program should also submit copies of their official undergraduate and graduate grades, results from the General Test of the GRE and a letter of reference from their doctoral advisor.

Systems Architecture and Engineering

Ethel Percy Andrus
Gerontology Center 240
(213) 740-4893
FAX: (213) 740-1120
Email: isedept@usc.edu

Program Director: F. Stan Settles, Ph.D.
Email: settles@usc.edu

Associate Director: George Friedman, Ph.D.
Email: Hprimate@aol.com

Faculty
IBM Chair in Engineering Management: F. Stan Settles, Ph.D. *(Industrial and Systems Engineering, Astronautics)*

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

TRW Professorship in Software Engineering: Barry Boehm, Ph.D. *(Computer Science, Industrial and Systems Engineering)*

Andrew and Erna Viterbi Chair in Communications: Solomon W. Golomb, Ph.D. *(Electrical Engineering, Mathematics)*

Professors: Michael O. Arbib, Ph.D. *(Biomedical Engineering, Computer Science, Neurobiology);* Barry Boehm, Ph.D. *(Computer Science, Industrial and Systems Engineering);* John Choma, Ph.D. *(Electrical Engineering, Electrophysics);* Maged Dessouky, Ph.D. *(Industrial and Systems Engineering);* Roger Ghanem, Ph.D *(Aerospace and Mechanical Engineering, Civil Engineering);* Solomon W. Golomb, Ph.D. *(Electrical Engineering, Mathematics);* Michael Gruntman, Ph.D. *(Astronautics and Space Technology);* Randolph Hall, Ph.D. *(Industrial and Systems Engineering);* Behrokh Khoshnevis, Ph.D. *(Industrial and Systems Engineering);* Yan Jin, Ph.D. *(Aerospace and Mechanical Engineering);* Joseph Kunc *(Astronautics and Space Technology, Physics);* Stephen C-Y Lu, Ph.D. *(Industrial and Systems Engineering, Aerospace and Mechanical Engineering);* Sami F. Masri, Ph.D. *(Civil Engineering, Mechanical Engineering);* Gerard Medioni, Ph.D. *(Computer Science);*

Jerry M. Mendel, Ph.D. *(Electrical Engineering);* James E. Moore, Ph.D. *(Industrial and Systems Engineering);* Sheldon M. Ross, Ph.D. *(Industrial and Systems Engineering);* F. Stan Settles, Ph.D. *(Industrial and Systems Engineering, Astronautics);* Firdaus Udwadia, Ph.D. *(Civil Engineering, Mechanical Engineering);* Charles L. Weber, Ph.D. *(Electrical Engineering);* L. Carter Welford, Ph.D. *(Civil Engineering);* Alan Wilner, Ph.D. *(Electrical Engineering)*

Associate Professors: Najmedin Meshkati, Ph.D. *(Industrial and Systems Engineering);* Mansour Rahimi, Ph.D. *(Industrial and Systems Engineering)*

Assistant Professor: Maria Yang, Ph.D. *(Industrial and Systems Engineering)*

Adjunct Professors: George Friedman, Ph.D. *(Industrial and Systems Engineering);* Michael Mann, Ph.D. *(Industrial and Systems Engineering)*

Research Professors: Malcolm R. Currie, Ph.D. *(Industrial and Systems Engineering);* Peter Will, Ph.D. *(Industrial and Systems Engineering)*

Senior Lecturer: Kurt Palmer *(Industrial and Systems Engineering)*

Emeritus Professors: Elliot Axelband, Ph.D. *(Electrical Engineering);* George Bekey, Ph.D. *(Electrical Engineering, Computer Science, Biomedical Engineering);* Ralph Keeney, Ph.D. *(Industrial and Systems Engineering);* Gerald Nadler, Ph.D., P.E. *(Industrial and Systems Engineering);* Eberhardt Rechtin, Ph.D. *(Industrial and Systems Engineering)*

Degree Requirements

Master of Science in Systems Architecture and Engineering

This program is recommended to graduate engineers and engineering managers responsible for the conception and implementation of complex systems. Emphasis is on the creative processes and methods by which complex systems are conceived, planned, designed, built, tested and certified. The Architecture experience can be applied to defense, space, aircraft, communications, navigation, sensors, computer software, computer hardware, and other aerospace and commercial systems and activities.

A minimum grade point average of 3.0 must be earned on all course work applied toward the master's degree in systems architecture and 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 Systems Architecture and Engineering is also subject to the following requirements:

(1) a total of at least 30 units is required, consisting of at least nine units in the Technical Management Area, nine units in the General Technical Area, and 12 units in the Technical Specialization area;

(2) every plan of study requires prior written approval by the director of the Systems Architecture and Engineering Program recorded on the study plan in the student's 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 24 of the 30 units must be taken in the Viterbi School of Engineering;

(5) units to be transferred (maximum of four with advisor approval) must have been taken prior to taking classes at USC; interruption of residency is not allowed;

(6) no more than six units of Special Topics courses (499 or 599) may be counted for this degree;

(7) thesis and directed research registrations may be allowed to individual students only by special permission of the supervising faculty member and the program director;

(8) a bachelor's degree in an engineering field and a minimum of three years systems experience are recommended prior to taking Systems Architecture and Design Experience courses. This program is not recommended for recent bachelor's degree graduates.

REQUIRED COURSES		UNITS
ISE 460	Engineering Economy, or	
ISE 561	Economic Analysis of	
	Engineering Projects	3
ISE 541	Systems Engineering	
	Theory and Practice	3
SAE 549	Systems Architecting	3

ONE OF THE FOLLOWING DESIGN EXPERIENCE COURSES OR THE EQUIVALENT

APPROVED BY THE DIRECTOR:		UNITS
AME 527	Elements of Vehicle and	
	Energy Systems Design	3
AME 556	Systems Architecture	
	Design Experience	3
CSCI 577a	Software Engineering	4

ELECTIVES	UNITS
Advisor-approved electives in Technical Management Area	3
Advisor-approved electives in General Technical Area	3
Advisor-approved electives in Technical Specialization Area	12

Courses Pertinent to the Program
Technical Management Area: nine units required including two required courses and one elective course.

REQUIRED		UNITS
ISE 460	Engineering Economy, or	
ISE 561	Economic Analysis of	
	Engineering Projects	3
ISE 541	Systems Engineering	
	Theory and Practice	3
Elective		3

ELECTIVES		UNITS
AME 589x	Management for Engineers	3
CE 556ab	Project Cost Estimating, Control, Planning and Scheduling	3-3
IOM 525*	Quality Improvement Methods	3
IOM 527*	Managerial Decision Analysis	3
IOM 537*	Information Systems Management for Global Operations	3
IOM 580*	Project Management	3
ISE 515	Engineering Product Management	3
ISE 544	Management of Engineering Teams	3
ISE 550	Engineering Management of Government-Funded Programs	3
ISE 562	Value and Decision Theory	3
ISE 585	Strategic Management of Technology	3
MOR 561*	Strategies in High-Tech Businesses	3

*USC Marshall School of Business course.

General Technical Area: nine units required including two required courses and one elective.

REQUIRED		UNITS
AME 527	Elements of Vehicle and Energy Systems Design, or	
AME 556	Systems Architecture Design Experience, or	
SAE 549	Systems Architecting	3
CSCI 577a	Software Engineering	4
Elective		3

ELECTIVES (TAKE ONE)		UNITS
CSCI 510	Software Management and Economics	3
CSCI 577ab	Software Engineering	4-4
IOM 535*	Database Management	3
ISE 542	Advanced Topics in Systems Engineering	3
ISE 550	Engineering Management of Government-Funded Programs	3
ISE 580	Advanced Concepts in Computer Simulation	3

*USC Marshall School of Business course.

Technical Specialization Area: Twelve units are required, usually in the student's present or intended technical specialty. Courses are intended to complement the student's prior education and experience toward becoming a well-rounded systems architect-engineer or architect-manager. With a few exceptions, the courses should come from the recommended list, and usually all from a single specialization.

The student may choose from a large variety of technical specializations spanning all departments in the Viterbi School of Engineering. Flexibility is emphasized in this choice; the program director is expected to work closely with the student in choosing the best set of courses to meet the student's need.

Several sample specializations are listed below but are not intended to be complete.

Recommended Courses
Aerospace and Mechanical Systems: AME 501, AME 502, AME 503, AME 504, AME 506, AME 521, AME 532a, AME 544, AME 548, AME 557, AME 560, AME 580, AME 581, AME 583, AME 585, AME 588.

Artificial Intelligence/Neural Networks: CSCI 460, CSCI 545, CSCI 561, CSCI 564, CSCI 566, CSCI 567, CSCI 574; EE 547.

Automation and Control Systems: EE 543a, EE 547, EE 585, EE 587, EE 588, EE 593.

Communication and Signal Processing Systems: EE 551, EE 562a, EE 563, EE 564, EE 567, EE 580, EE 582, EE 583, EE 599.

Computer and Information Systems: CSCI 485, CSCI 551, CSCI 585, EE 552, EE 554, EE 561, EE 562a, EE 574, EE 658.

Construction: CE 501, CE 519, CE 525ab, CE 533, CE 536, CE 556ab, CE 583.

Engineering Management Systems: ISE 515, ISE 530, ISE 535, ISE 541, ISE 544, ISE 550, ISE 562, ISE 580, ISE 585, ISE 599.

Integrated Media Systems: EE 469, EE 522, EE 555, EE 569, EE 596, EE 599 – Immersive Audio Signal Processing, EE 669; CSCI 450, CSCI 480, CSCI 551, CSCI 574, CSCI 576, CSCI 585, CSCI 588.

Manufacturing Systems: ISE 511, ISE 514, ISE 516, ISE 517, ISE 544, ISE 570; AME 588; EE 561ab.

Network-centric: CSCI 402, CSCI 530, CSCI 551, CSCI 555, CSCI 558L, CSCI 577ab, EE 550, SAE 574.

Software Process Architecture: CSCI 510, CSCI 577b, CSCI 665; ISE 544, ISE 562, ISE 564, EE 554, EE 557.

Systems: ISE 515, ISE 520, ISE 525, ISE 527, ISE 528, ISE 532, ISE 535, ISE 536, ISE 538, ISE 541, ISE 542, ISE 544, ISE 562, ISE 580, ISE 585; EE 598.

Graduate Certificate in Systems Architecture and Engineering
The graduate certificate in systems architecture and engineering is designed for practicing engineers engaged in the creation and design of complex innovative systems, in aerospace and commercial fields. Entering students are expected to have a bachelor's degree in engineering or a related field from an accredited institution. Three years of industry experience are recommended. Students are required to earn a cumulative B average or higher in courses taken for the certificate. The courses taken for the certificate may be applied later to the Master of Science in Systems Architecture and Engineering.

REQUIRED COURSES–CHOOSE FOUR		UNITS
ISE 460	Engineering Economy, or	
ISE 561	Economic Analusis of Engineering Projects	3
ISE 515	Engineering Project Management	3
ISE 541	Systems Engineering Theory and Practice	3
ISE 542	Advanced Topics in Systems Engineering	3
ISE 544	Management of Engineering Teams	3
SAE 549	Systems Architecting	3

In addition, one 3- or 4-unit elective course shall be taken from the list of those approved for the Master of Science in Systems Architecture and Engineering.

All programs of study will be approved by the director of the Systems Architecture and Engineering program.

Courses of Instruction

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

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

549 Systems Architecting (3, FaSp) Introduction to systems architecture in aerospace, electrical, computer, and manufacturing systems emphasizing the conceptual and acceptance phases and using heuristics. *Prerequisite:* B.S. degree in a related field of engineering.

574 Net-Centric Systems Architecting and Engineering (3, FaSp) In-depth examination of the technical design approaches, tools, and processes to enable the benefits of net-centric operations in a networked systems-of-systems.

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.

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

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