
USC Viterbi School of Engineering



Civil engineering student Katie Hickey was a member of the 20-student Viterbi canoe team, which took home several prizes in the annual intercollegiate competition where students design and race concrete canoes. “The issues that we, as a team, had to deal with parallel exactly what I expect to see when I start my career,” said co-captain Hickey. The competition is an annual project for Viterbi’s Society of Civil Engineers, which, at 86 years, is the nation’s third oldest chapter.

Courses in engineering were first offered at USC in the 1905-06 academic year in the basement of one of the oldest buildings on campus. Today, 168 full-time, tenure track faculty (and more than 300 total faculty) serve about 1,800 undergraduates and 4,000 graduate students, utilizing extensive and technically advanced laboratories, classrooms and live interactive high-speed Internet broadcast systems. Government and industry annually fund more than \$160 million worth of research.

The Viterbi School is innovative, elite and internationally recognized for creating new models of education, research and commercialization firmly rooted in real world needs. The school’s first priorities are the education of outstanding students and the pursuit and publication of research.

As the school’s faculty and students extend the frontiers of engineering knowledge through their research, they also apply engineering and technology to address societal challenges. The school stimulates and encourages qualities of scholarship, leadership and character that mark the true academic and professional engineer — to serve California, the nation and the world. At the Viterbi School, we call this the enabling power of Engineering+.

The school prepares students to translate invention to innovation and advances the continuing education of engineering and scientific personnel to provide professional engineering leadership to solve community, regional, national and global problems.

Viterbi undergraduate support programs have increased selectivity, retention and graduation rates. The Klein Institute for Undergraduate Engineering Life fosters leadership, cross-disciplinary activity and globalization; the Freshman Academy exposes first-year students to current research; and the Engineering Writing Program (EWP) develops communication skills.

Viterbi graduate education is outstanding preparation for advanced research and professional careers. The Ph.D. program is built around fellowships, teaching assistantships and research appointments, and has produced a steady increase in doctoral degrees. The master’s and professional programs are national and global leaders in advanced training for professional engineers.

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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 Engineering (Biochemical Engineering); Biomedical (Electrical Engineering); Biomedical (Mechanical Engineering); Chemical Engineering; Chemical Engineering (Biochemical Engineering); Chemical Engineering (Environmental Engineering); Chemical Engineering (Nanotechnology); Chemical Engineering (Petroleum Engineering); Chemical Engineering (Polymer/Materials); Civil Engineering; Civil Engineering (Building Science); Civil Engineering (Environmental Engineering); Civil Engineering (Structural Engineering); Computer Engineering and Computer Science; Computer Science; Computer Science/Business Administration; Computer Science (Games); Electrical Engineering; Electrical Engineering (Computers); Environmental Engineering; Industrial and Systems Engineering; Industrial and Systems Engineering (Information Systems Engineering); Mechanical Engineering; Mechanical Engineering (Petroleum Engineering) and Physics/Computer Science.

Minor programs are offered in: Astronautical Engineering; Computer Science; Construction Planning and Management; Craniofacial and Dental Technology; Engineering Management; Engineering Technology Commercialization; Environmental Engineering; Interactive Multimedia; Materials Science; Petroleum Engineering and Polymer Science; 3-D Animation; Video Game Design and Management; Video Game Programming; Web Technology and Applications.

Graduate curricula leading to the Master of Science in: Aerospace and Mechanical Engineering (Computational Fluid and Solid Mechanics); Aerospace and Mechanical Engineering (Dynamics and Control); Aerospace Engineering; Astronautical Engineering; Biomedical Engineering; Biomedical Engineering (Medical Imaging and Imaging Informatics); Chemical Engineering; Civil Engineering; Civil Engineering (Construction Engineering); Civil Engineering (Environmental Engineering); Civil Engineering (Geotechnical Engineering); Civil Engineering (Structural Engineering); Civil Engineering (Transportation Engineering); Computer Engineering; Computer Science; Computer Science (Computer Networks); Computer Science (Computer Security); Computer Science (Game Development); Computer Science (High Performance Computing and Simulations); Computer Science (Human Language Technology); Computer Science (Intelligent Robotics); Computer Science (Multimedia and Creative Technologies); Computer Science (Software Engineering); Electrical Engineering; Electrical Engineering (Computer Networks); Electrical Engineering (Electric Power); Electrical Engineering (Multimedia and Creative Technologies); Electrical Engineering (VLSI Design); Engineering Management; Environmental Engineering; Financial Engineering; Green Technologies; Health Systems Management Engineering; Industrial and Systems Engineering; Manufacturing Engineering; Materials Engineering; Materials Science; Mechanical Engineering; Medical Device and Diagnostic Engineering; Operations Research Engineering; Petroleum Engineering; Petroleum Engineering/Smart Oilfield Technologies; Product Development Engineering; and Systems Architecting and Engineering.

Graduate curricula leading to the Master of Construction Management.

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

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.

Through the Graduate School, graduate curricula leading to the Doctor of Philosophy in: Aerospace Engineering; Astronautical 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.

Graduate certificates in: Astronautical Engineering; Engineering Technology Commercialization; Health Systems Operations; Network Centric Systems; Smart Oilfield Technologies; Software Engineering; Systems Architecting and Engineering; and Transportation Systems.

Undergraduate Program Accreditation

The aerospace engineering, chemical engineering, civil engineering, computer engineering and computer science, electrical engineering, environmental engineering, industrial and systems engineering, and mechanical engineering programs are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET): 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone: (410) 347-7700. All of the options within each of these programs are covered by this accreditation.

Undergraduate Degrees

Change of Major to Engineering

USC undergraduate students who have not been admitted to the Viterbi School of Engineering may apply to add an engineering major with the approval of the Associate Dean for Admission and Student Affairs. Students seeking approval to add an engineering major must complete required

prerequisite courses and submit a Request to Change Major to Engineering form to the Admission and Student Affairs Office. Approval is granted on the basis of academic performance at USC and in the required prerequisite courses.

Non-engineering students may complete a maximum of four engineering courses. No further engineering courses may be taken unless a change of major request has been approved.

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 engineering (electrical engineering), 133 units; biomedical engineering (mechanical engineering), 132 units; chemical engineering, 129 units; chemical engineering (biochemical engineering), 133 units; chemical engineering (environmental engineering), 132 units; chemical engineering (nanotechnology), 128 units; chemical engineering (petroleum engineering), 133 units; chemical engineering (polymer/materials science engineering), 136 units; civil engineering, 131 units; civil engineering (building science), 133 units; civil engineering (environmental engineering), 130 units; civil engineering (structural), 131 units; computer science/business administration, 137 units; computer science (games), 128 units; electrical engineering, 131 units; environmental engineering, 132-134 units.

Not more than 4 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 61 and 241 for more information. In addition, students pursuing a degree in computer science must meet the

foreign language requirement described on page 244.

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 and the WRIT 140 or WRIT 130 requirement; these students are understood to have satisfied USC's general education requirements when they have satisfied the general education requirements and lower level writing requirement at their previous institution. All students must, however, complete the WRIT 340 requirement.

Students in aerospace, astronomical 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 61 and 241.

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 Division. 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 (advisement and free tutoring) provided by the Viterbi Admission and Student Affairs Division.

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, by May 1 for the summer session and by August 15 for the fall semester. Late petitions will not be accepted. A non-refundable \$50 fee must accompany all readmission petitions.

Special Educational Opportunities

Viterbi Admission and Student Affairs Division

The Viterbi Admission and Student Affairs Division, 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.

The Viterbi Admission and Student Affairs Division enables engineering students to have a successful experience at USC.

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 Leadership Academy") prior to their first semester at USC.

Contact the Center for Engineering Diversity at (213) 740-1999 for more information.

Klein Institute for Undergraduate Engineering Life

The Klein Institute for Undergraduate Engineering Life (KIUEL) was established to provide Viterbi undergraduates with a variety of personal and professional activities to enhance undergraduate engineering student life experiences outside the classroom. KIUEL plans programs around leadership, service learning and globalization, and cross-disciplinary learning. Past KIUEL events have included the KIUEL Weekend for Leaders, the Viterbi Book Club, the KIUEL Showcase and the Technology Assistance Program. For more information, visit viterbi.usc.edu/kiuel.

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 since 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.

First Year Excellence

The First Year Excellence (FYE) program helps first year students develop strong connections to the university and the Viterbi school. FYE promotes academic exploration and success through its co-curricular programs, support services and resources during students' first year. Freshman academies, introductory courses and the Viterbi Spotlight Program help guide students as they explore engineering. Academic advisors work with all freshman students to make sure they are on track academically and to help them acclimate to college life and USC. Free tutoring, group-led supplemental instruction sessions, workshops and seminars on time management and networking with faculty, and a fall transfer dinner are made available to all students to help them accomplish their goals.

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, career preparation workshops, 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 the Viterbi school include: Accenture, Amgen, Alcon Laboratories, Inc., BAE Systems, Chevron Corporation, Cisco Systems, Inc., Clark Construction, Hewlett-Packard Development Company, L.P., IBM, Intel, Jet Propulsion Laboratory, Kiewit Corporation, Lockheed Martin Corporation, Microsoft Corporation, Morley Builders, NASA, Northrop Grumman Corporation, Parsons Corporation, QUALCOMM Incorporated, Raytheon, Stryker Corporation, Turner Construction Company, Walt Disney Imagineering and Yahoo.

Cooperative Education

By participating in the Co-op Program, students can earn degree credit and 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 one summer work experience 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.

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 another location 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.

International Exchange Programs

The Viterbi School of Engineering Undergraduate International Exchange Program gives students the opportunity to broaden their exposure to the global context of engineering theory and practice by spending a semester or year abroad in a challenging academic environment at an international host institution. The International Exchange Program allows students to satisfy technical electives and/or approved degree requirements by attending approved partner institutions. This program is open to students entering their junior or senior year. Students apply at the Engineering Student Affairs Office. Candidates must meet all admission requirements of both the Viterbi School of Engineering as well as those of the international host institution. Contact the Admission and Student Affairs Office for a complete list of international exchange partners.

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).

Minor in Engineering Technology Commercialization

The undergraduate minor in engineering technology commercialization is interdisciplinary in nature, requiring courses from both the business and engineering schools and providing education in the economic, technological and management aspects of commercializing new engineering ideas. Business courses include those in technology entrepreneurship, case studies in new ventures and an elective in business plans. Engineering courses cover engineering economy and engineering law. There is also a dean's seminar jointly taught by the business and engineering schools. Elective courses in technologically specific areas of commercialization, such as biomedical devices, are also included.

This program is especially suited to engineering majors.

A minimum of 16 units is required for the minor. Courses required for a student's major that are listed below are not included in the unit total.

REQUIRED COURSES (15 UNITS)		UNITS
BAEP 452	Cases in Entrepreneurship	4
BUAD 301	Technical Entrepreneurship	3
CE 404	Business and Intellectual Property Law for Engineers	3
ENGR 493x	Dean's Seminar in Entrepreneurship	2
ISE 460	Engineering Economy	3
ELECTIVE COURSES (2-4 UNITS)		UNITS
BAEP 454	The Entrepreneurial Business Plan	4
BME 416	Development and Regulation of Medical Products	3
ISE 344	Engineering Team Management	3
ISE 440	Work, Technology, and Organization	3
ISE 490x	Directed Research	2-3

Directed research units can be in any department and supervised by any faculty but must be approved by the faculty chair of USC Stevens Institute for Innovation, a dean within the engineering school or a designate identified by an engineering dean to count toward this minor. This ensures that the directed research is relevant to technology commercialization.

Graduate Degrees

General Requirements

The Viterbi School of Engineering recommends candidates for the Master of Science degree in: aerospace engineering, astronautical engineering, biomedical engineering, chemical engineering, civil engineering, computer engineering, computer science, electrical engineering, environmental engineering, financial engineering, green technologies, health systems management engineering, industrial and systems engineering, manufacturing engineering, materials engineering, materials science, mechanical engineering, medical device and diagnostic engineering, operations research engineering, petroleum engineering, product development engineering, system safety and security, and systems architecting and engineering. Several areas of emphasis and specialization are available within these disciplines.

All graduate work in the Viterbi School of Engineering is under the jurisdiction of the Viterbi School 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

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 Graduate 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. 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.

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 Graduate School. In some departments letters of recommendation and a statement of purpose 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

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 the general test are required for admission to full graduate standing in most programs. Consult the department office for further information.

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.

Progressive Degree Programs

The progressive degree program allows qualified undergraduate students the opportunity to complete an integrated program of study joining a bachelor's degree program and a master's degree program in the same or different departments. Applicants for a progressive degree program must have completed 64 units of course work applicable to their undergraduate degree since graduating from high school. (AP units, IB units and course work taken prior to high school graduation are excluded). Applicants must submit their application prior to completion of 96 units of course work. Normally, the application is submitted in the fall semester of the third year of enrollment at USC. The application for admission to a progressive master's program must be accompanied by a departmentally approved course plan proposal and two letters of recommendation. All application materials can be obtained from the Viterbi Admission and Student Affairs Office (RTH 110, viterbi.usc.edu/pdp).

Progressive degree program students must fulfill all the requirements for both the bachelor's degree and the master's degree. The total number of units for the master's degree, however, may be reduced by a maximum of one-third. A minimum of two-thirds of the units required for the master's degree must be at or above the 500 level. Students will be subject to undergraduate academic progress standards and policies while in undergraduate status and master's academic progress standards and policies while in graduate status. The degrees may be awarded separately, but the master's degree will not be awarded before the undergraduate degree. The time limit for completing a progressive degree program is 12 semesters. For more information, refer to page 84.

General Requirements for the Master of Science

Residence Requirements

The typical 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. Up to four transferred units will be accepted from another engineering school upon verification by Degree Progress and 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.

Deficiency Courses

New students may be required to demonstrate satisfactory preparation for the graduate program with previously completed course work. In cases where preparation is not demonstrated, up to 9 units of deficiency course work may be required in addition to the normal degree requirements.

Credit for required deficiency courses may not be applied toward a graduate degree. A deficiency course within the same discipline taken after the higher level course has been passed will not be available for unit or grade point credit.

Placement Examinations

Enrollment in certain 500- and 600-level courses in the disciplines of computer engineering, computer science and electrical engineering will require a student to either take and pass the corresponding 400-level prerequisite at USC, or pass a placement exam in the corresponding course.

Not all 400-level prerequisite courses taken instead of a placement exam are available for degree credit. No unit or grade point credit is given for placement exams. Please consult with an academic advisor or refer to the department Web sites at www.cs.usc.edu and ee.usc.edu for information on specific courses and placement exam details.

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 Directed Research and 594ab Master's 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 Viterbi Office of Master's and Professional Programs 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.

Progress Toward the Degree

Graduate students are expected to make regular progress toward their degrees as defined by the faculty of their respective departments and within the time limits allowed. Graduate students' progress and performance are reviewed each semester. Students making unsatisfactory progress receive a formal written warning and are placed on a semester of academic warning with specific conditions to be met for continuation in the program. Please refer to catalogue sections Academic Warning and Dismissal of Graduate Students, page 36; Grade Point Average Requirements, page 85; and the Web site of the Office of Master's and Professional Programs (MAPP) at viterbi.usc.edu/mapp or the Office of Doctoral Programs at viterbi.usc.edu/students/phd.

Department Approval for Non-Major Courses

Prior departmental approval is required for non-major courses to be taken and applied toward a graduate degree. Students are advised to consult with the faculty advisor for formal written permission to take courses outside the major department for degree credit.

A copy of the faculty advisor's written approval must be kept in the department file and retained by the student until graduation.

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 student's academic department. This application should be returned to the student's academic department. 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.

Deficiency Courses

New students may be required to demonstrate satisfactory preparation for the graduate program with previously completed course work. In cases where preparation is not demonstrated, up to 9 units of deficiency course work may be required in addition to the normal degree requirements.

Credit for required deficiency courses may not be applied toward a graduate degree. A deficiency course within the same discipline taken after the higher level course has been passed will not be available for unit or grade point credit.

Placement Examinations

Enrollment in certain 500- and 600-level courses in the disciplines of computer engineering, computer science and electrical engineering will require a student to either take and pass the corresponding 400-level prerequisite at USC, or pass a placement exam in the corresponding course.

Not all 400-level prerequisite courses taken instead of a placement exam are available for degree credit. No unit or grade point credit is given for placement exams. Please consult with an academic advisor or refer to the department Web sites at www.cs.usc.edu and ee.usc.edu for information on specific courses and placement exam details.

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.

Progress Toward the Degree

Graduate students are expected to make regular progress toward their degrees as defined by the faculty of their respective departments and within the time limits allowed. Graduate students' progress and performance are reviewed each semester. Students making unsatisfactory progress receive a formal written warning and are placed on a semester of academic warning with specific conditions to be met for continuation in the program. Please refer to catalogue sections Academic Warning and Dismissal of Graduate Students, page 36; Grade Point Average Requirements, page 85; and the Web site of the Office of Master's and Professional Programs (MAPP) at viterbi.usc.edu/mapp or the Office of Doctoral Programs at viterbi.usc.edu/students/phd.

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 the 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 engineering, astronautical engineering, chemical engineering, civil engineering, electrical engineering, environmental engineering, industrial and systems engineering, mechanical engineering, 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 6 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 6 units of course work. In order to have the project credited toward the degree, the student must register in 690 Directed Research during the course of the project; total 690 Directed Research registration should be 6 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 student's academic department. 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 810 to maintain continuous enrollment in the program. Results of the examination are reported to the Viterbi Office of Master's and Professional Programs and forwarded to the Office of Academic Records and Registrar.

Transfer Credits

Up to 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.

Thirteen Doctor of Philosophy (Ph.D.) programs are offered: aerospace engineering, astronautical 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.

Deficiency Courses

New students may be required to demonstrate satisfactory preparation for the graduate program with previously completed course work. In cases where preparation is not demonstrated, up to 9 units of deficiency course work may be required in addition to the normal degree requirements.

Credit for required deficiency courses may not be applied toward a graduate degree. A deficiency course within the same discipline taken after the higher level course has been passed will not be available for unit or grade point credit.

Placement Examinations

Enrollment in certain 500- and 600-level courses in the disciplines of computer engineering, computer science and electrical engineering will require a student to either take and pass the corresponding 400-level prerequisite at USC, or pass a placement exam in the corresponding course.

Not all 400-level prerequisite courses taken instead of a placement exam are available for degree credit. No unit or grade point credit is given for placement exams. Please consult with an academic advisor or refer to the department Web sites at www.cs.usc.edu and ee.usc.edu for information on specific courses and placement exam details.

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.

Progress Toward the Degree

Graduate students are expected to make regular progress toward their degrees as defined by the faculty of their respective departments and within the time limits allowed. Graduate students' progress and performance are reviewed each semester. Students making unsatisfactory progress receive a formal written warning and are placed on a semester of academic warning with specific conditions to be met for continuation in the program. Please refer to catalogue sections Academic Warning and Dismissal of Graduate Students, page 36; Grade Point Average Requirements, page 85; and the Web site of the Office of Master's and Professional Programs (MAPP) at viterbi.usc.edu/mapp or the Office of Doctoral Programs at viterbi.usc.edu/students/phd.

Special Educational Opportunities

Distance Education Network

Established in 1972, the USC Viterbi School of Engineering's Distance Education Network (DEN) is a pioneer in the distance learning arena, using cutting-edge technology to enable professional engineers to take USC engineering courses for graduate degree credit without coming to the campus. Today, over 1,300 DEN students, enrolled around the world, are pursuing over 40 degree programs – more choices than at any other research university. DEN breaks down geographical and scheduling barriers, allowing students to take classes anytime and anywhere. Remote DEN students receive support from administrative and technical staff and enjoy access to all things the Viterbi School has to offer.

The Viterbi School has made it possible for all on-campus students enrolled in the school's graduate courses to receive free access to the archived lectures of courses offered via DEN. This valuable study aid enables students to review lectures throughout the semester.

For more information, visit viterbi.usc.edu/map.

Graduate Certificate in Engineering Technology Commercialization

The graduate certificate in engineering technology commercialization provides USC engineers with the knowledge, skill set and confidence to manage intellectual property and technology innovation and enables them to connect with colleagues in industry and venture capital to address real-world problems through technology transfer and commercialization. This certificate program provides an opportunity for graduate students to understand the process of evaluating the feasibility of their ideas and inventions and the confidence to commercialize their ideas. It also provides an opportunity for practicing engineers to obtain an academically rigorous foundation of technology commercialization which drives their company. The program is interdisciplinary in nature, requiring courses from both the business and engineering schools and providing education in the economic, technological and management aspects of commercializing new engineering ideas.

Applicants to this program are expected to have a degree in engineering or science from an accredited institution, an undergraduate GPA of at least 3.0 on a 4.0 scale, and a score of at least 650 on the quantitative portion and 400 on the verbal portion of the GRE test.

A total of 12 units is required for the certificate.

REQUIRED CORE COURSES (6 UNITS)

BAEP 551	Introduction to New Ventures	3
ISE 585	Strategic Management of Technology	3

ELECTIVE COURSES (6 UNITS)

ISE 515	Engineering Project Management	3
ISE 517	Modern Enterprise Systems	3
ISE 527	Quality Management for Engineers	3
ISE 544	Management of Engineering Teams	3
ISE 555	Invention and Technology Development	3
ISE 565	Law and Finance for Engineering Innovation	3

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)

ENGR 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.

ENGR 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.

ENGR 102 Engineering Freshman Academy (2, Fa) Introduction to the profession of engineering. Ethical, political and societal consequences of engineering innovations and the impact of engineering on everyday life. Team project and guest lectures. Open to freshmen only. Graded CR/NC.

ENGR 150L Engineering Science and Systems: From Humans to Robots (3, Fa) Hands-on multidisciplinary engineering course that uses robotics as a theme to cover material from all areas of engineering. Laboratory; programming; team projects; end-of-semester exhibition. Open only to freshmen. *Recommended preparation:* Basic programming experience (e.g., C, C++, C#, Java, Python).

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

ENGR 305 Engineering Biology Matters (3, FaSp) Engineering students will learn biological phenomena in the context of engineering principles and explore biological mechanisms and processes as analogies for designing engineered systems. *Recommended preparation:* CHEM 105aL, MASC 110L.

ENGR 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.

ENGR 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.

ENGR 493x Dean's Seminar in Entrepreneurship (2, Sp) Overview of starting and developing a new business. Discussions with successful business leaders and entrepreneurs. Not available for students admitted to the Entrepreneur Program. Open only to seniors or graduate students in business or engineering. Graded CR/NC. (Duplicates credit in former BUAD 493x.)

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

ENGR 501x Engineering Writing and Communication for Master's Students (3, FaSp) Academic and discipline-specific writing skills. Emphasis on structure of discourse and writing process. Presentation and oral communication skills also addressed. Graded CR/NC. Credit Restrictions: May be taken for degree credit only toward M.S. degrees in Industrial and Systems Engineering; Engineering Management; Manufacturing Engineering and Entrepreneurship; Operations Research Engineering; and the Master of Engineering in Environmental Quality Management.

ENGR 502x Writing Skills for Engineering Ph.D. Students (3, FaSp) Writing of engineering curriculum- and research-related projects for Ph.D. students. Focus is on conference papers, dissertations and proposals, journal articles, and other forms. Graded CR/NC. Not available for degree credit for the master's degree.

ENGR 503x Oral Communication Skills for Engineering Ph.D. Students (3, FaSp) Academic and professional presentation skills for Ph.D. students. Preparation for qualifying exams, conference paper presentations, and other forms of oral communication. Use of visual aids and poster displays included. Graded CR/NC. Not available for degree credit for the master's degree.

ENGR 504x Fellowship Proposal Writing for Engineering Ph.D. Students (2, FaSp) Preparation of essays and other materials for research fellowship applications. Graded CR/NC. Open only to Ph.D. engineering students. Not available for degree credit.

ENGR 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:* CSCI 561, ISE 511L, and AME 588.

ENGR 596 Internship in Engineering (1, max 3, FaSpSm) Part-time or full-time, practical work experience in the student's field of study. The internship must be located at an off-campus facility. Students are individually supervised by faculty. May not be taken until the student has completed at least one semester of enrollment in the graduate program. Graduate standing in engineering. Graded CR/NC.

Aerospace and Mechanical Engineering

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

Mechanical Engineering Headquarters:
 Olin Hall of Engineering
 Room 430
 (213) 740-8762
 FAX: (213) 740-8071
 Email: ame@usc.edu

Chair: Geoffrey R. Spedding, Ph.D.

Faculty

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

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

Smith International Professor of Mechanical Engineering: Tony Maxworthy, Ph.D.**

Professors: Charles Campbell, Ph.D.; Julian Domaradzki, Ph.D.**; Marijan Dravinski, Ph.D.; Fokion Eglolfopoulos, Ph.D.; Daniel Erwin, Ph.D.* (*Aeronautics*); Henryk Flashner, Ph.D.; Roger Ghanem, Ph.D. (*Civil and Environmental Engineering*);

Mike Gruntman, Ph.D. (*Aeronautics*); Yan Jin, Ph.D.; Michael E. Kassner, Ph.D. (*Materials Science*); Joseph Kunc, Ph.D. (*Aeronautics*); Physics); Terence G. Langdon, Ph.D., D.Sc.** (*Materials Science and Geological Sciences*); Stephen C-Y Lu, Ph.D. (*Industrial and Systems Engineering*); Sami F. Masri, Ph.D. (*Civil and Environmental 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.; Geoffrey Spedding, Ph.D.*; Costas Synolakis, Ph.D. (*Civil and Environmental Engineering*); Firdaus E. Udwadia, Ph.D. (*Civil and Environmental Engineering, Information and Operations Management, Systems Architecting Engineering and Mathematics*); Hai Wang, Ph.D.; Bingen Yang, Ph.D.

Associate Professor: Geoffrey R. Shifflett, Ph.D.*

Assistant Professors: Veronica Eliasson, Ph.D.; Andrea Hodge, Ph.D.; Eva Kanso, Ph.D.; Denis Phares, Ph.D.; Tait Pottebaum, Ph.D.

Associate Professor of Engineering Practice:
 M. Oussama Safadi, Ph.D.*

Research Associate Professor: Adam Fincham, Ph.D.

Research Assistant Professors: Megumi Kawasaki, Ph.D.; Maria Teresa Perez Prado, Ph.D.

Research Associates: Anita Penkova, Ph.D.; Roxana Tiron, Ph.D.

Emeritus Professors: Fred Browand, 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.*; Donald E. Shemansky, 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 endeavor to prepare students to achieve the following objectives:

- (1) Graduates will be professionals working in engineering or in related areas such as computer science, business, law, medicine or public service, at both large- and small-scale businesses.
- (2) Graduates will engage in lifelong learning, such as continuing their education through graduate school or professional development courses.
- (3) Graduates will make use of modern and cutting-edge tools, such as advanced computer software and state-of-the-art laboratory equipment.
- (4) Graduates will be both competent technical innovators and industrial leaders.
- (5) Graduates will incorporate societal, ethical and environmental considerations into technical decisions.
- (6) Graduates will effectively communicate 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 563.

COMPOSITION/WRITING REQUIREMENT	UNITS
WRIT 130 Analytical Writing	4
WRIT 340 Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61)	UNITS
General education ⁺	20

PRE-MAJOR REQUIREMENTS	UNITS
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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: Optics and Modern Physics	4

Chemistry Elective

CHEM 105aL*	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4

MAJOR REQUIREMENTS	UNITS
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Aerospace and Mechanical Engineering

AME 105	Introduction to Aerospace Engineering	4
AME 150L	Introduction to Computational Methods	4
AME 201	Statics	3
AME 204	Strength of Materials	3
AME 261	Basic Flight Mechanics	4
AME 301	Dynamics	3
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 309	Dynamics of Fluids	4
AME 310	Engineering Thermodynamics I	3

AME 341aLbL	Mechoptronics Laboratory I and II	3-3
AME 404	Computational Solutions to Engineering Problems	3
AME 441aL	Senior Projects Laboratory	3
AME 451	Linear Control Systems I	3

Astronautics

AME 481	Aircraft Design, or	4
ASTE 420**	Spacecraft Design	3
ASTE 280	Astronautics and Space Environment I	3

MAJOR ELECTIVES	UNITS
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AME core electives***	9
Technical electives****	6
Free electives**	1-2
Total units:	128-129

*Satisfies GE Category III requirement.

**Students planning to take ASTE 420 must take 2 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 3 units of 490 Directed Research course work can be used to satisfy the technical elective requirement.

⁺The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

Minor in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 564.

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; 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.

Master of Science, 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 thesis units.

REQUIRED CORE COURSES (24 UNITS)	UNITS
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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 590	Directed Research	1-12
AME 599	Special Topics	2-4, max 9
ASTE 545	Computational Techniques in Rarefied Gas Dynamics	3
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 662.

Master of Science in Systems Architecting and Engineering

See the listing under Systems Architecting and Engineering, page 663.

Engineer in Aerospace Engineering

Requirements for the Engineer in aerospace engineering are the same as the general requirements. Three to 6 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.

Graduate Certificate in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 571.

Mechanical Engineering Degrees

Bachelor of Science in Mechanical Engineering

The requirement for the degree is 128 units. A cumulative GPA of 2.0 or higher is required for all upper division course work in engineering, science and mathematics. See the common requirements for undergraduate degrees section, page 564.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61)		UNITS
General education ⁺		20

PRE-MAJOR REQUIREMENTS		UNITS
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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: Optics and Modern Physics	4

Chemistry Elective

CHEM 105aL*	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4

MAJOR REQUIREMENTS		UNITS
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Aerospace and Mechanical Engineering

AME 101L	Introduction to Mechanical Engineering and Graphics	3
AME 150L	Introduction to Computational Methods	4
AME 201	Statics	3
AME 204	Strength of Materials	3
AME 301	Dynamics	3
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 309	Dynamics of Fluids	4
AME 310	Engineering Thermodynamics I	3
AME 331	Heat Transfer	3
AME 341aLbL	Mechoptronics Laboratory I and II	3-3
AME 404	Computational Solutions to Engineering Problems	3
AME 409	Senior Design Project	4
AME 441aL	Senior Projects Laboratory	3
AME 443L	Control Systems Laboratory	3
AME 451	Linear Control Systems Analysis, or	
AME 420	Engineering Vibrations	3
<i>Materials Science</i>		
MASC 310	Materials Behavior and Processing	3

MAJOR ELECTIVES		UNITS
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AME core electives**		6
AME design elective***		3
Technical electives		6
Total units:		128

*Satisfies GE Category III requirement.

**Any upper division course in AME.

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

⁺The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

Bachelor of Science in Mechanical Engineering (Petroleum Engineering)

The requirement for the degree is 128 units. A cumulative GPA of 2.0 or higher is required for all upper division course work in engineering, science and mathematics. See the common requirements for undergraduate degrees section, page 564.

COMPOSITION/WRITING REQUIREMENT		UNITS
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WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61)		UNITS
General education ⁺		20
PRE-MAJOR REQUIREMENTS		UNITS
<i>Math Requirement</i>		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
<i>Physics Requirement</i>		
PHYS 151L*	Fundamentals of Physics I: Mechanics, Waves and Sounds	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4
<i>Chemistry Elective</i>		
CHEM 105aL*	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry, or	
MASC 110L	Materials Science	4
MAJOR REQUIREMENTS		UNITS
<i>Aerospace and Mechanical Engineering</i>		
AME 101L	Introduction to Mechanical Engineering and Graphics	3
AME 150L	Introduction to Computational Methods in Mechanical Engineering	4
AME 201	Statics	3
AME 204	Strength of Materials	3
AME 301	Dynamics	3
AME 308	Computer-Aided Analysis for Aero-Mechanical Design	3
AME 309	Dynamics of Fluids	4
AME 310	Engineering Thermodynamics I	3
AME 331	Heat Transfer	3
AME 341aLbL	Mechoptronics Laboratory I and II	3-3
AME 404	Computational Solutions to Engineering Problems	3
AME 408	Computer-Aided Design of Mechanical Systems	3
AME 409	Senior Design Project	4
AME 441aL	Senior Projects Laboratory	3
AME 443L	Control Systems Laboratory	3
AME 451	Linear Control Systems I	3
AME 463L	Introduction to Transport Processes in Porous Media	3

Petroleum Engineering

PTE 461	Formation Evaluation	3
PTE 464L	Petroleum Reservoir Engineering	3
PTE 465L	Drilling Technology and Subsurface Methods	3

MAJOR ELECTIVES		UNITS
AME core elective**		3
Total units:		128

*Satisfies GE Category III requirement.

**Any upper division course in AME.

⁺The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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 795.

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.

Master 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 574.

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*.

AME 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.

AME 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.

AME 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.

AME 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 151L.

AME 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.

AME 222 Fundamentals of Audio Engineering (3, Fa) (Enroll in EE 222)

AME 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 150L.

AME 291 Undergraduate Design Projects I (1, max 4, FaSpSm) Analysis, design, fabrication, and evaluation 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.

AME 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; *recommended preparation*: PHYS 151L.

AME 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.

AME 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.

AME 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.

AME 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.

AME 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.

AME 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 151L, high-level programming language.

AME 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.

AME 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.

AME 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 152L, MATH 126.

AME 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.

AME 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; *recommended preparation:* MATH 125, MATH 126, MATH 226; PHYS 151L, PHYS 152L, PHYS 153L.

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

AME 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.

AME 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.

AME 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.

AME 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.

AME 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.

AME 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.

AME 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.

AME 423L Loudspeaker and Sound-System Design (3, FaSp) (Enroll in EE 423L)

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

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

AME 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.

AME 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.

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

AME 443 Control Systems Laboratory (3, Sp) Vibration measurement and analysis; simulation, design, and experimental verification of mechanical control systems; identification of system parameters, implementation of controllers, verification of closed-loop performance via experimentation and stimulation. (Duplicates credit in former AME 442bL.) Prerequisite: AME 420 or AME 451 or EE 482.

AME 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.

AME 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.

AME 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.

AME 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.

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

AME 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.

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

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

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

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

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

AME 465L Drilling Technology and Sub-surface Methods (3) (Enroll in PTE 465L)

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

AME 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.

AME 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.

AME 490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit.

AME 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.

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

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

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

AME 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.

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

AME 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.

AME 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.

AME 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.

AME 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.

AME 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 microgravity combustion, turbulent combustion and hypersonic propulsion. *Recommended preparation:* AME 513.

AME 515 Advanced Problems in Heat Conduction (3) 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. *Recommended preparation:* AME 331, AME 526.

AME 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.

AME 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.

AME 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.

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

AME 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.

AME 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.

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

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

AME 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.

AME 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.

AME 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.

AME 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.

AME 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.

AME 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.

AME 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. *Recommended preparation:* 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. *Recommended preparation:* AME 511 or AME 530a, AME 535a.

AME 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.

AME 539 Multi-body Dynamics (3, Fa) Kinematics and kinetics of rigid body motion, quaternions; elastic vibrations of continua; geometric and material nonlinearities; Galerkin methods; meshless finite elements; complex dynamical systems; computational methods.

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

AME 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.

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

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

AME 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.

AME 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.

AME 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.

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

AME 550ab Seminar in Aerospace and Mechanical Engineering (1-1, FaSp) Recent developments and research in aerospace and mechanical engineering and related fields. Oral and written reports. Graded CR/NC. Open only to AME graduate students.

AME 551 Mechanical Behavior of Engineering Materials (3) (Enroll in MASC 551)

AME 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.

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

AME 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.

AME 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.

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

AME 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.

AME 567 Collaborative Engineering Principles and Practice (3, Sp) (Enroll in ISE 567)

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

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

AME 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 525ab or AME 525 and AME 526.

AME 577 Survey of Energy and Power for a Sustainable Future (3, Fa) Power production includes conventional fossil fuels, synthetic fuels, hydroelectric, solar, wind, geothermal, biomass, and nuclear. The environmental consequences of various energy sources are discussed. Open only to graduate students and AME seniors. *Recommended preparation:* B.S. in Aerospace Engineering, Mechanical Engineering or Physics.

AME 578 Modern Alternative Energy Conversion Devices (3, Sp) Alternative energy/power conversion including fuel cells, photovoltaic, batteries, and biologically inspired energy processes; biomass conversion and utilization; Environmental implications of alternative energy processes. Open only to graduate students and AME seniors. *Recommended preparation:* B.S. in Aerospace Engineer, Mechanical Engineering or Physics.

AME 579 Combustion Chemistry and Physics (3, Fa) Thermodynamics of combustion processes. Reaction mechanisms of hydrocarbon combustion. Pollutant formation. Theories and application of thermochemical kinetics and reaction rate theories. Transport in reacting flows.

AME 581 Introduction to Nuclear Engineering (3, Fa) Review of basic nuclear physics, binding energy, reactor kinetics, thermal transport in reactor systems, radioactivity, shielding, reactor safety and health effects of radiation, risk assessment. Open only to graduate students. *Recommended preparation:* Undergraduate degree in engineering; AME 310, MATH 245, PHYS 153L.

AME 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.

AME 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.

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

AME 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.

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

AME 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.

AME 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.

AME 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 530b.

AME 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 530b.

AME 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.

AME 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.

AME 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.

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

AME 645 Uncertainty Modeling and Stochastic Organization (3) (Enroll in CE 645)

AME 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 530b.

AME 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 530b.

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

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

AME 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.

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

Applied Mechanics

Kaprielian Hall 210
(213) 740-0603
FAX: (213) 744-1426
Email: ceedept@usc.edu
www.usc.edu/cee

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 563.

COMPOSITION/WRITING REQUIREMENTS		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	4
		8
GENERAL EDUCATION (SEE PAGE 61)		UNITS
General education* +		24

PRE-MAJOR REQUIREMENTS

Math Requirement		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
MATH 445	Mathematics of Physics and Engineering II	4

Physics Requirement

PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152	Fundamentals of Physics II: Electricity and Magnetism	4
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4

Chemistry Elective

CHEM 105aL	General Chemistry	4
		36

MAJOR REQUIREMENTS

Aerospace and Mechanical Engineering		UNITS
AME 310	Engineering Thermodynamics I	3
AME 341a	Mechoptronics Laboratory I	3
AME 441aL	Senior Projects Laboratory	3

Civil Engineering

CE 205	Statics	2
CE 225	Mechanics of Deformable Bodies	3
CE 309	Fluid Mechanics	3
CE 325	Dynamics	3

Electrical Engineering

EE 326L	Essentials of Electrical Engineering	4
		24

MAJOR ELECTIVES

Free electives**	4
Technical electives	28
Approved electives in computer programming	4
Total units:	128

* GE Category VI and WRIT 140 are taken concurrently.

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

†The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

Astronautical Engineering

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astronautics.usc.edu

Chair: Daniel A. Erwin, Ph.D.*

Faculty

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

Professors: Daniel A. Erwin, Ph.D.* (Aerospace Engineering); Mike Gruntman, Ph.D.

(Aerospace Engineering, Systems Architecting Engineering); Darrell L. Judge, Ph.D. (Physics and Astronomy); Joseph A. Kunc, Ph.D. (Physics and Astronomy, Aerospace Engineering, Systems Architecting Engineering)

Associate Professor: Joseph Wang, Ph.D.

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

Adjunct Associate Professor: Michael Kezirian, Ph.D.

Research Professor: Herbert Schorr, Ph.D. (Computer Science)

Research Associate Professor: Sergey Gimelshein, Ph.D.

*Recipient of university-wide or school teaching award.

Aerospace Engineering Honor Society: Sigma Gamma Tau

Degree Requirements

Educational Program Objectives

The Bachelor of Science degree program in Astronautical Engineering has the following objectives:

(1) Graduates will apply technical skills in mathematics, science and engineering to solve complex problems of modern astronautical engineering practice.

(2) Graduates will use advanced tools and techniques of engineering, and will innovate to advance the state of the art when needed.

(3) Graduates will design and build complex engineering systems according to specifications and subject to technical as well as economic constraints.

(4) Graduates will communicate with skill as members and leaders of multidisciplinary teams.

(5) Graduates will make engineering decisions using high professional and ethical standards, taking into account their global, environmental and societal context.

(6) Graduates will learn continuously throughout their careers in order to adapt to new knowledge and discoveries and to meet future challenges.

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 563.

COMPOSITION/WRITING REQUIREMENTS		UNITS
WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	4
		8

GENERAL EDUCATION (SEE PAGE 61)		UNITS
General education* +		20

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
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
Elective	Technical elective**	15
Total units:		128

* Satisfies GE Category III requirement.

** 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 3 units of 490 course work can be used to satisfy the technical elective requirement.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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 course work consists of a minimum of 18 units. 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 units: 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 defense/aerospace industry, government research and development centers, and laboratories and academia. 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 (12 UNITS)		UNITS
ASTE 470	Spacecraft Propulsion	3
ASTE 520	Spacecraft System Design	3
ASTE 535	Space Environments and Spacecraft Interactions	3
ASTE 580	Orbital Mechanics I	3

CORE ELECTIVE REQUIREMENT (6 UNITS — CHOOSE TWO COURSES)		UNITS
ASTE 501ab	Physical Gas Dynamics	3-3
ASTE 523	Design of Low Cost Space Missions	3
ASTE 527	Space Studio Architecting	
3 ASTE 552	Spacecraft Thermal Control	3
ASTE 553	Systems for Remote Sensing from Space	3
ASTE 554	Spacecraft Sensors	3
ASTE 556	Spacecraft Structural Dynamics	3
ASTE 570	Liquid Rocket Propulsion	
3 ASTE 572	Advanced Spacecraft Propulsion	3
ASTE 581	Orbital 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

TECHNICAL ELECTIVE REQUIREMENT (6 UNITS)

Two 3-unit courses. Students are advised to select these two elective courses from the list of core electives or from other courses in astronautical engineering or from other science and engineering graduate courses, as approved by the faculty advisor. 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 (CHOOSE ONE COURSE: 3 UNITS)		UNITS
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3
CE 529a	Finite Element Analysis	3
EE 517	Statistics for Engineers	3
PHYS 510	Methods of Theoretical Physics	3

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

Areas of Concentration:

Students choose core elective and technical elective courses that best meet their educational objectives. Students can also concentrate their studies in the desired areas by selecting corresponding core elective courses. Presently, ASTD faculty suggest the following areas of concentration:

SPACECRAFT PROPULSION

Choose two core electives from:

ASTE 501ab	Physical Gas Dynamics	3-3
ASTE 570	Liquid Rocket Propulsion	3
ASTE 572	Advanced Spacecraft Propulsion	3
ASTE 584	Spacecraft Power Systems	3

SPACECRAFT DYNAMICS

Choose two core electives from:

ASTE 556	Spacecraft Structural Dynamics	3
ASTE 581	Orbital Mechanics II	3
ASTE 583	Space Navigation: Principles and Practice	3
ASTE 585	Spacecraft Attitude Control	3
ASTE 586	Spacecraft Attitude Dynamics	3

SPACE SYSTEMS DESIGN

Choose two core electives from:

ASTE 523	Design of Low Cost Space Missions	3
ASTE 527	Space Studio Architecting	3

(SAE 549 System Architecting I, 3 units, is also suggested as a technical elective for this area of concentration.)

SPACECRAFT SYSTEMS

Choose two core electives from:

ASTE 552	Spacecraft Thermal Control	3
ASTE 553	Systems for Remote Sensing from Space	3
ASTE 554	Spacecraft Sensors	3
ASTE 584	Spacecraft Power Systems	3

SPACE APPLICATIONS

ASTE 527	Space Studio Architecting	3
ASTE 553	Systems for Remote Sensing from Space	3
ASTE 554	Spacecraft Sensors	3

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 one to two 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 566. 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 566. 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 Division of Astronautical Engineering, can be obtained from the ASTD student advisor and program coordinators.

Certificate in Astronautical Engineering

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 584	Spacecraft Power Systems	3
ASTE 556	Spacecraft Structural Dynamics	3	ASTE 585	Spacecraft Attitude Control	3
ASTE 572	Advanced Spacecraft Propulsion	3	ASTE 586	Spacecraft Attitude Dynamics	3
ASTE 580	Orbital Mechanics I	3	ASTE 599	Special Topics	3
ASTE 581	Orbital Mechanics II	3	Most classes are available through the USC Distance Education Network (DEN).		
ASTE 583	Space Navigation: Principles and Practice	3			

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)

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.

ASTE 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 152L.

ASTE 291 Team Projects I (1, max 4, FaSp) Participation in ASTE undergraduate student team projects. Intended for lower-division students or those with little prior project experience.

ASTE 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 311ab.) *Prerequisite:* MATH 245, PHYS 153L.

ASTE 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 153L.

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

ASTE 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.

ASTE 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 301b.

ASTE 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.

ASTE 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.

ASTE 490x Directed Research (2-8, max 8, FaSpSm) Individual research and readings. Not available for graduate credit.

ASTE 491 Team Projects II (1, max 4, FaSp) Participation in ASTE undergraduate student team projects. Intended for students with prior project experience.

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

ASTE 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 520ab.) *Prerequisite:* ASTE 501a.

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

ASTE 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.

ASTE 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.

ASTE 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.)

ASTE 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.)

ASTE 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 501a and skill in FORTRAN programming.

ASTE 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.

ASTE 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.

ASTE 554 Spacecraft Sensors (3, Fa)

Spacecraft sensors from concept and design to building, testing, interfacing, integrating, and operations. Optical and infrared sensors, radiometers, radars, phased arrays, signal processing, noise reduction. Graduate standing in engineering or science. *Recommended preparation:* ASTE 520.

ASTE 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.

ASTE 570 Liquid Rocket Propulsion (3, Sp)

Liquid-propelled rocket propulsion systems. Capillary devices for gas-free liquid acquisition in zero gravity. Ground and in-orbit operations. Propellant life predictions and spacecraft end-of-life de-orbiting strategies. *Prerequisite:* ASTE 470.

ASTE 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.

ASTE 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.)

ASTE 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.

ASTE 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.

ASTE 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.)

ASTE 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.

ASTE 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.)

ASTE 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.

ASTE 594abz Master's Thesis (2-2-0, FaSpSm)

Credit on acceptance of thesis. Graded IP/CR/NC.

ASTE 599 Special Topics (2-4, max 9)

Course content to be selected each semester from current developments in astronautics, space technology, and related fields.

ASTE 690 Directed Research (1-4, max 8, FaSpSm)

Laboratory studies of specific problems for candidates for the degree Engineer in Astronautical Engineering. Graded CR/NC.

ASTE 694abz Thesis (2-2-0, FaSpSm)

Required for the degree Engineer in Astronautical Engineering. Credit on acceptance of thesis. Graded IP/CR/NC.

ASTE 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.

ASTE 794abcdz Doctoral Dissertation (2-2-2-0, FaSpSm)

Credit on acceptance of dissertation. Graded IP/CR/NC.

Biomedical Engineering

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Email: bmedept@usc.edu
bme.usc.edu

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

Faculty

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

Chonette Chair in Biomedical Technology: David Z. D'Argenio, Ph.D.

David Packard Chair in Engineering: Theodore W. Berger, Ph.D.

Cornelius J. Pings Chair in Biomedical Sciences: Mark Humayun, Ph.D. (*Ophthalmology*)

Viterbi Early Chair in Engineering: Ellis F. Meng, Ph.D. (*Electrical Engineering*)

Professors: Michael O. Arbib, Ph.D. (*Computer Science, Neurobiology*); Michel Baudry, Ph.D. (*Natural Sciences and Mathematics*); Theodore W. Berger, Ph.D. (*Neurobiology*); Richard N. Bergman, Ph.D. (*Physiology and Biophysics*); Roberta D. Brinton, Ph.D. (*Molecular Pharmacology and Toxicology*); Peter S. Conti, M.D., Ph.D. (*Radiology*); David Z. D'Argenio, Ph.D.*; Norberto M. Grzywacz, Ph.D.; H. K. Huang, D.Sc. (*Radiology*); Mark S. Humayun, Ph.D. (*Ophthalmology*); Michael C.K. Khoo, Ph.D. (*Pediatrics*); Kwang Jin Kim, Ph.D. (*Medicine and Physiology*); Richard Leahy, Ph.D. (*Electrical Engineering and Radiology*); Gerald E. Loeb, M.D.; Anupam Madhukar, Ph.D. (*Chemical Engineering and Materials Science, Physics*); Jill McNitt-Gray, Ph.D.

(*Exercise Science*); Chrysostomos Niekas, Ph.D. (*Electrical Engineering*); Dennis O'Leary, Ph.D. (*Otolaryngology, Physiology and Biophysics*); Terence D. Sanger, M.D., Ph.D. (*Neurology, Biokinesiology*); 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*); Stanley M. Yamashiro, Ph.D. (*Electrical Engineering*)

Associate Professors: Daniel P. Holschneider, M.D. (*Psychiatry*); Sandra Howell, Ph.D. (*Biokinesiology and Physical Therapy*); Tzung K. Hsiai, M.D., Ph.D.; David Huang, M.D., Ph.D. (*Ophthalmology*); Hossein Jadvar, M.D., Ph.D. (*Radiology*); Zhong-Lin Lu, Ph.D. (*Psychology*); Jill McNitt-Gray, Ph.D. (*Exercise Science*); Bartlett W. Mel, Ph.D.; Krishna Nayak, Ph.D. (*Electrical Engineering*); Francisco Valero-Cuevas, Ph.D. (*Biokinesiology*); James D. Weiland, Ph.D. (*Ophthalmology*); Jesse T. Yen, Ph.D.

Assistant Professors: Tansu Celikel, Ph.D. (*Neurobiology*); Noah Malmstadt, Ph.D. (*Chemical Engineering and Materials Science*); J. Andrew MacKay, Ph.D. (*Pharmacology and Pharmaceutical Sciences*); Ellis F. Meng, Ph.D.

Associate Professor of Engineering Practice: Jean-Michel I. Maarek, Doc.Ing.

Research Professors: Daniel L. Farkas, Ph.D. (*Cedars-Sinai Medical Center*); Jonathan G. Lasch, Ph.D. (*AMI-USC*); Alfred E. Mann, M.S. (*AMI-USC*); Vasilis Z. Marmarelis, Ph.D. (*Electrical Engineering*); Donald J. Marsh, M.D.; Robert V. Shannon, Ph.D. (*House Ear Institute*)

Research Associate Professors: Qian-Jie Fu, Ph.D. (*House Ear Institute*); John J. Granacki, Ph.D. (*Electrical Engineering-Systems/ISI*); Qifa Zhou, Ph.D.

Research Assistant Professors: Jonathan M. Cannata, Ph.D.; Rahman Davoodi, Ph.D.; Alireza Dibazar, Ph.D.; Changhong Hu, Ph.D.; Clara Lajonchere, Ph.D.; Rongsong Li, Ph.D.; Eun Jin Lee, Ph.D.; Dong Song, Ph.D.

Associate Professor of Research: Brent J. Liu, Ph.D. (*Radiology*)

Assistant Professors of Research: Bo Han, Ph.D. (*Surgery*); Paraq Mallick, Ph.D. (*Medicine*); Rex A. Moats, Ph.D. (*Pathology, 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 Assistant Professors: Leonid Litvak, Ph.D. (*Advanced Bionics Corp.*); Philip Requejo, Ph.D. (*Rancho Los Amigos Medical Center and Kinesiology*)

Emeritus Professors: George A. Bekey, Ph.D. (*Electrical Engineering, Computer Science and Speech Science*); Edward K. Blum, Ph.D. (*Mathematics, Computer Science*)

*Recipient of university-wide or school teaching award.

Degree Requirements

Educational Program Objectives

Graduates of our undergraduate program are expected to:

- engage in a professional career in the biomedical or other related industries, or enroll in advanced graduate studies including medical school;
- work in a technically competent manner to address challenges in engineering or their chosen professions, taking into consideration ethical and societal concerns;
- work in multidisciplinary teams and communicate effectively with other engineers and professionals;
- continue to develop their technical knowledge and professional skills, as evidenced by participation or leadership in relevant professional societies; continuing education; or attendance at relevant workshops, meetings or seminars.

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 563.

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

COMPOSITION/Writing REQUIREMENT UNITS

WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61) UNITS

General education* +	20
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PRE-MAJOR REQUIREMENTS UNITS

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

Chemistry Elective

CHEM 105aL**	General Chemistry, or	
CHEM 115aL**	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4

MAJOR REQUIREMENTS UNITS

Biomedical Engineering

BME 101	Introduction to Biomedical Engineering	3
BME 210	Biomedical Computer Simulation Methods	3
BME 302L	Medical Electronics	4
BME 402	Control and Communication in the Nervous System	3
BME 403	Physiological Systems	3
BME 405L	Senior Projects: Measurements and Instrumentation	4
BME 410	Introduction to Biomaterials and Tissue Engineering	3
BME 414	Rehabilitation Engineering	3
BME 423	Statistical Methods in Biomedical Engineering	3

Biology

BISC 120L**	General Biology: Organismal Biology and Evolution	4
BISC 220L	General Biology: Cell Biology and Physiology	4
BISC 320L	Molecular Biology	4

Chemistry

CHEM 322aLbL	Organic Chemistry	4-4
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Electrical Engineering

EE 150L	Engineering Computational Methods	3
EE 200L	Foundations of Electrical Engineering Systems	4
EE 202L	Linear Circuits	4

MAJOR ELECTIVES UNITS

Technical electives	9
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Total units:	128
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*WRIT 140 is taken concurrently with GE Category VI.

**Satisfies GE Category III requirement.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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 563.

COMPOSITION/Writing REQUIREMENT UNITS

WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61) UNITS

General education* +	20
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PRE-MAJOR REQUIREMENTS UNITS

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

Chemistry Elective

CHEM 105aL**	General Chemistry, or	
CHEM 115aL**	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4

MAJOR REQUIREMENTS UNITS

Biomedical Engineering

BME 101	Introduction to Biomedical Engineering	3
BME 210	Biomedical Computer Simulation Methods	3
BME 402	Control and Communication in the Nervous System	3
BME 403	Physiological Systems	3
BME 405L	Senior Projects: Measurements and Instrumentation	4
BME 410	Introduction to Biomaterials and Tissue Engineering	3
BME 416	Development and Regulation of Medical Products	3
BME 423	Statistical Methods in Biomedical Engineering	3

Biology

BISC 120L**	General Biology: Organismal Biology and Evolution	4
BISC 220L	General Biology: Cell Biology and Physiology	4
BISC 320L	Molecular Biology	4
BISC 330L	Biochemistry	4

Chemistry

CHEM 322aLbL	Organic Chemistry	4-4
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Chemical Engineering

CHE 330	Chemical Engineering Thermodynamics	3
CHE 350	Introduction to Separation Processes	3
CHE 460L	Chemical Process Dynamics and Control	3
CHE 489	Biochemical Engineering	3

Electrical Engineering

EE 150L	Engineering Computational Methods	3
EE 200L	Foundations of Electrical Engineering Systems	4

Materials Science

MASC 310	Materials Behavior and Processing	3
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MAJOR ELECTIVES	UNITS
Technical elective	2
Total units:	132

*GE Category VI is taken concurrently with WRIT 140.
 **Satisfies GE Category III requirement.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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. See common requirements for undergraduate degrees section, page 563.

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

GENERAL EDUCATION (SEE PAGE 61)	UNITS
General education* +	20

PRE-MAJOR REQUIREMENTS	UNITS
<i>Math Requirement</i>	
MATH 125 Calculus I	4
MATH 126 Calculus II	4
MATH 226 Calculus III	4
MATH 245 Mathematics of Physics and Engineering I	4
MATH 445 Mathematics of Physics and Engineering II	4

<i>Physics Requirement</i>	
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

<i>Chemistry Elective</i>	
CHEM 105aL** General Chemistry, or CHEM 115aL** Advanced General Chemistry	4
CHEM 105bL General Chemistry, or CHEM 115bL Advanced General Chemistry	4

MAJOR REQUIREMENTS	UNITS
<i>Biomedical Engineering</i>	
BME 101 Introduction to Biomedical Engineering	3
BME 210 Biomedical Computer Simulation Methods	3
BME 402 Control and Communication in the Nervous System	3
BME 403 Physiological Systems	3
BME 405L Senior Projects: Measurements and Instrumentation	4
BME 423 Statistical Methods in Biomedical Engineering	3
BME 425 Basics of Biomedical Imaging	3

<i>Biology</i>	
BISC 220L General Biology: Cell Biology and Physiology	4
BISC 320L Molecular Biology	4

<i>Chemistry</i>	
CHEM 322aL Organic Chemistry	4

<i>Electrical Engineering</i>	
EE 101 Introduction to Digital Logic	3
EE 150L Engineering Computational Methods	3
EE 200L Foundations of Electrical Engineering Systems	4
EE 201L Introduction to Digital Circuits	4
EE 202L Linear Circuits	4
EE 338 Physical Electronics	3
EE 348L Electronic Circuits I	4
EE 357 Basic Organization of Computer Systems	3

MAJOR ELECTIVES	UNITS
Technical electives	4
Total units:	133

*WRIT 140 is taken concurrently with GE Category VI.
 **Satisfies GE Category III requirement.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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. See common requirements for undergraduate degrees section, page 563.

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

GENERAL EDUCATION (SEE PAGE 61)	UNITS
General education* +	20

PRE-MAJOR REQUIREMENTS	UNITS
<i>Math Requirement</i>	
MATH 125 Calculus I	4
MATH 126 Calculus II	4
MATH 226 Calculus III	4
MATH 245 Mathematics of Physics and Engineering I	4

<i>Physics Requirements</i>	
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

<i>Chemistry Elective</i>	
CHEM 105aL** General Chemistry, or CHEM 115aL** Advanced General Chemistry	4
CHEM 105bL General Chemistry, or CHEM 115bL Advanced General Chemistry	4

MAJOR REQUIREMENTS	UNITS
<i>Aerospace and Mechanical Engineering</i>	
AME 201 Statics	3
AME 204 Strength of Materials	3
AME 301 Dynamics	3
AME 302 Design of Dynamic Systems	3
AME 308 Computer-Aided Analysis for Aero-Mechanical Design	3
AME 309 Dynamics of Fluids	4

<i>Biomedical Engineering</i>	
BME 101 Introduction to Biomedical Engineering	3
BME 210 Biomedical Computer Simulation Methods	3
BME 402 Control and Communication in the Nervous System	3
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

Biology

BISC 220L	General Biology: Cell Biology and Physiology	4
BISC 320L	Molecular Biology	4

Chemistry

CHEM 322aL	Organic Chemistry	4
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Electric Engineering

EE 150L	Engineering Computational Methods	3
EE 200L	Foundations of Electrical Engineering Systems	4

Materials Science

MASC 310	Materials Behavior and Processing	3
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MAJOR ELECTIVES

Technical electives	6
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Total units: 132

* WRIT 140 is taken concurrently with GE Category VI.

** Satisfies GE Category III requirement.

†The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

Minor in Craniofacial and Dental Technology

For a complete listing, see the School of Dentistry, page 514.

Minor in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 564.

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 degree 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

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
		<hr/> 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 with departmental approval.

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

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

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
		<hr/> 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 and product development. The course of study requires successful completion of 28 units of course work and has been designed to be completed in three semesters of full-time study. Students in the program will complete a 19-unit core as well as selecting a 6-unit specialization (or "track") and one elective from a list provided by the department.

REQUIRED COURSES

REQUIRED COURSES	UNITS	
BME 501	Advanced Topics in Biomedical Systems, or Advanced Studies of the Nervous System	4
BME 502	Advanced Studies of the Nervous System	4
BME 513	Signal and Systems Analysis	3
BME 650	Biomedical Measurement and Instrumentation	3
MPTX 511	Introduction to Medical Product Regulation, or Development and Regulation of Medical Products	3
BME 416	Regulation of Medical Products	3
MPTX 515	Quality Systems and Standards, or Quality Management for Engineers	3
ISE 527	Quality Management for Engineers	3
ISE 545	Technology Development and Implementation	3
Technical elective		3

Complete 6 units from one track from the following lists: 6

Regulation Track

MPTX 513	Regulation of Medical Devices and Diagnostics	3
RSCI 527	Medical Product Safety	3

Medical Technology and Device Science Track

BME 535	Ultrasonic Imaging	3
BME 551	Introduction to Bio-MEMS and Nanotechnology	3
BME 552	Neural Implant Engineering	3
BME 620L	Applied Electrophysiology	4

Product Development Track

ISE 515	Engineering Project Management	3
ISE 555	Invention and Technology Development	3
		<hr/> 28

Technical Elective (one course)

Applicable courses include: AME 503, BME 511, BME 535, BME 551, ISE 507, ISE 508, ISE 544, MPTX 517, RSCI 528 and courses listed in alternate tracks to that chosen. Other courses may be applicable; please see an advisor for approval.

Viterbi Integrated Master of Science Program (VIP) for the General Master of Science in Biomedical Engineering

The Viterbi Integrated Master of Science Program (VIP) will allow selected undergraduates from U.S. institutions partnered with the Viterbi School to complete a general Master of Science in Biomedical Engineering with a 6-unit reduction of the total 28 units required.

The VIP Master of Science in Biomedical Engineering is subject to the following requirements: (1) a total of at least 22 units is required; (2) all units must be taken in biomedical engineering; (3) all units must be taken at the 500 or 600 level; (4) minimum grade point average of 3.0 must be earned on all course work applied toward the master's degree in biomedical engineering. This average must also be achieved on all course work attempted at USC beyond the bachelor's degree.

The students will complete 400-level preparatory courses at their undergraduate institution before entering USC. The 400-level courses may be taken toward the undergraduate requirements. They must be acceptable equivalents to at least two of the USC courses listed below:

BME 402	Control and Communication in the Nervous System	3
BME 403	Physiological Systems	3
BME 404	Biomechanics	3
BME 405L	Senior Projects: Measurements and Instrumentation	4
BME 410	Introduction to Biomaterials and Tissue Engineering	3
BME 423	Statistical Methods in Biomedical Engineering	3
BME 425	Basics of Biomedical Imaging	3

After admission, students will complete the following courses (22 units) within three semesters:

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, or Technical Elective	2-2-0
	Electives	4
		3

Students applying to the VIP must be recommended by a faculty representative at a partner undergraduate institution; complete the regular graduate admission application (with exception of the GRE); and hold junior standing in biomedical engineering with a 3.5 GPA or better on major related course work.

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. By the end of the third semester of graduate study the student must have completed the Ph.D. screening examination. Subsequently, 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 Process

By the end of the third semester of graduate study, all students must have completed the screening examination process 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 Examination

The qualifying examination will normally be taken during the fourth semester of full-time academic study. The examination requires 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.

Graduate Certificate in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 571.

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*.

BME 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.

BME 201 Biomedical Engineering Practice (2, Fa) Examination of the technical and practical challenges involved in the development of medical devices, including neural implants, in industry and the clinical setting. *Recommended preparation:* BME 101.

BME 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:* EE 150L; *corequisite:* MATH 245.

BME 302L Medical Electronics (4, Sp) Electronic design and measurements for medical applications. Use of integrated circuits, bio-potential measurements, static and dynamic calibration of physiological transducers. *Prerequisite:* EE 200L.

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

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

BME 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 220L, BME 210, MATH 245.

BME 403 Physiological Systems (3, Fa) A thorough bioengineering treatment of the physiological properties of various mammalian organ systems: e.g., cardiovascular, respiratory, renal, and musculoskeletal. *Prerequisite:* BISC 220L, MATH 245; *corequisite:* EE 200L.

BME 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 151L; MATH 245; AME 201.

BME 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 200L.

BME 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 322aL.

BME 412 Craniofacial and Dental Technology (4) (Enroll in DENT 412)

BME 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.

BME 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.

BME 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.

BME 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 bio-magnetism. *Prerequisite:* PHYS 153L.

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

BME 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.

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

BME 490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit.

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

BME 501 Advanced Topics in Biomedical Systems (4, FaSp) Advanced topics in selected biomedical systems: cardiopulmonary, neuromuscular, renal and endocrine.

BME 502 Advanced Studies of the Nervous System (4, Fa) Advanced topics on the structure and function of the nervous system examined from the viewpoint of computational systems science.

BME 505abL Laboratory Projects in Biomedical Engineering (4-4, FaSp) Integration of biomedical science, engineering principles and state-of-the-art technology for the study of selected physiological systems in the laboratory setting. Laboratory. (Duplicates credit in former BME 605abL.) Graded IP to letter.

BME 511 Physiological Control Systems (3, Fa) Application of control theory to physiological systems; static analysis of closed-loop systems; time-domain analysis of linear control identification methods; nonlinear control. *Recommended preparation:* BME 513.

BME 513 Signal and Systems Analysis (3, Sp) 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.

BME 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.

BME 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.

BME 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.

BME 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.

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

BME 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.

BME 536 Ultrasonic Transducers (3, Fa) Background and foundation covering the design, fabrication and testing of ultrasonic transducers and arrays. Design approaches, modeling tools will be discussed. Design project assigned.

BME 551 Introduction to Bio-MEMS and Nanotechnology (3, Sp) 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.

BME 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.

BME 575L Computational Neuroengineering (3, Sp) Introduction to computational modeling in neuroengineering, anchored in examples of brain function. Topics include transduction, synapses, spiking, networks, normalization, learning, Bayesian models, and Kalman filtering. *Prerequisite:* BME 502.

BME 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.

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

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

BME 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.

BME 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. *Recommended preparation:* BME 513.

BME 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 or BME 502 or CSCI 574.

BME 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; stereopsis; motion; contours; object recognition. Open to graduate students only. *Prerequisite:* NEUR 524 or BME 502 or CSCI 574.

BME 675 Computational Vision (3, Irregular) 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.

BME 680 Modeling and Simulation of Physiological Systems (3, Irregular) Mathematical theories and computation techniques for modeling physiological systems, with emphasis on cardiorespiratory, metabolic-endocrine, and neuronal functions.

BME 686 Introduction to Biomedical Research (3, Irregular) 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.

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

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

Chemical Engineering – Mork Family Department of Chemical Engineering and Materials Science

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Chair: Theodore T. Tsotsis, Ph.D.

Director: Katherine S. Shing, Ph.D.

Faculty

Zohrab A. Kaprielian Dean's Chair in Engineering and Chester F. Dolley Chair in Petroleum Engineering: Yannis C. Yortsos, Ph.D.

Fluor Early Career Chair in Engineering: Andrea M. Armani, Ph.D. (*Electrical Engineering, Materials Science*)

M.C. Gill Chair in Composite Materials: Steven R. Nutt, Ph.D. (*Aerospace and Mechanical Engineering*)

Omar B. Milligan Chair in Petroleum Engineering: Iraj Ershaghi, Ph.D.

N.I.O.C. Chair in Petroleum Engineering: Muhammad Sahimi, Ph.D.

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

Fluor Professor in Process Engineering: S. Joe Qin, Ph.D.

William M. Keck Professor of Energy Resources: Donald M. Paul, Ph.D.

Gordon S. Marshall Professor in Engineering Technology: Dongxiao Zhang, Ph.D. (*Civil and Environmental Engineering*)

Kenneth T. Norris Professor of Engineering: Anupam Madhukar, Ph.D. (*Physics*)

Professors: Edward Crandall, Ph.D., M.D. (*Medicine*); P. Daniel Dapkus, Ph.D. (*Electrical Engineering*); Martin Gundersen, Ph.D. (*Electrical Engineering*); Rajiv K. Kalia, Ph.D. (*Physics and Computer Science*); Michael Kassner, Ph.D. (*Aerospace and Mechanical Engineering*); Terence G. Langdon, Ph.D., D.Sc. (*Aerospace and Mechanical Engineering and Earth Sciences*); Florian Mansfeld, Ph.D.; Aiichiro Nakano, Ph.D. (*Computer Science, Physics and Biomedical Engineering*); George Olah, Ph.D. (*Chemistry*); Richard Roberts, Ph.D. (*Chemistry*); Richard Stegemeier, M.S. Eng.; Armand R. Tanguay, Jr., Ph.D. (*Electrical and Biomedical Engineering*); Mark E. Thompson, Ph.D. (*Chemistry*); Priya Vashishta, Ph.D. (*Physics, Computer Science and Biomedical Engineering*)

Associate Professors: Wenji Victor Chang, Ph.D.; Edward Goo, Ph.D.; C. Ted Lee, Jr., Ph.D.*; Katherine S. Shing, Ph.D.*; Chongwu Zhou, Ph.D. (*Electrical Engineering*)

Assistant Professors: Malancha Gupta, Ph.D.; Andrea Maria Hodge, Ph.D. (*Aerospace and Mechanical Engineering*); Kristian Jessen, Ph.D.; Noah Malmstadt, Ph.D.; Pin Wang, Ph.D.

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

Research Professors: Fred Aminzadeh, Ph.D.; Peter Will, Ph.D. (*Information Sciences Institute*)

Emeritus Professors: Elmer L. Dougherty, Ph.D.; Murray Gershenzon, Ph.D. (*Electrical Engineering*); Ronald Salovey, Ph.D.*; William G. Spitzer, Ph.D. (*Physics and Electrical Engineering*)

*Recipient of university-wide or school teaching award.

Chemical Engineering Honor Society: Omega Chi Epsilon

Degree Requirements

Educational Program Objectives

Chemical engineering is the only engineering discipline that makes extensive use of chemical transformations (reactions) in addition to physical transformations (refining, molding or machining) to achieve added value. 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. Our various curricula are designed to produce graduates who are broadly educated as well as highly adaptable.

Graduates of the Bachelor of Science in Chemical Engineering programs are prepared to achieve any of the following accomplishments:

- To obtain employment in organizations where physical, chemical or biochemical transformations are utilized to produce products and services that benefit society.
- To pursue graduate or professional education in a variety of related fields.
- To engage in continuous personal and professional development through lifelong learning.
- To assume leadership roles in their employment organization or community.

Bachelor of Science in Chemical Engineering Degrees

The Department of Chemical Engineering offers six Bachelor of Science degrees: chemical engineering (129 units); chemical engineering (biochemical engineering) (133 units); chemical engineering (environmental engineering) (132 units); chemical engineering (nanotechnology) (128 units); chemical engineering (petroleum engineering) (133 units); and chemical engineering (polymer/materials science) (133 units).

Sample student schedules are located on the department Web page (chems.usc.edu).

Common Requirements for all Bachelor of Science Degrees (108 units)

See also common requirements for undergraduate degrees section, page 563.

COMPOSITION/WRITING COURSES		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
GENERAL EDUCATION (SEE PAGE 61)**		UNITS
General education ⁺		20
CHEMISTRY COURSES		UNITS
CHEM 105aL	General Chemistry, or	4
CHEM 115aL	Advanced General Chemistry	
CHEM 105bL	General Chemistry, or	4
CHEM 115bL	Advanced General Chemistry	
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	3
CHE 350	Introduction to Separation Processes	3
CHE 442	Chemical Reactor Analysis	3
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	3
CHE 480	Chemical Process and Plant Design	3

OTHER COURSES **UNITS**

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

*GE Category VI is taken concurrently with WRIT 140.

**Diversity course must double count as a GE course in calculating the total unit count for the degree.

***Satisfies GE Category III requirement.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

++Students in the biochemical option may not choose BUAD 301 as their engineering elective.

Additional Requirements for Individual Degrees*Bachelor of Science in Chemical Engineering*

The requirement for the degree is 129 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in 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	4
CHEM 430b	Physical Chemistry	

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 133 units.* A scholarship average of C (2.0) or higher is required in all upper division courses taken in 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	3
CHE 485	Computer-Aided Chemical Process Design	

*Students in the biochemical engineering option must take 50 engineering units total to graduate.

Bachelor of Science in Chemical Engineering (Environmental 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 chemical engineering and 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	3
ENE 429	Air Pollution Control	

Bachelor of Science in Chemical Engineering (Nanotechnology)

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 chemical engineering, materials science, electrical engineering and chemistry. In addition to the previously listed common requirements, students must also take the following courses:

CHEMISTRY COURSE **UNITS**

CHEM 453	Advanced Inorganic Chemistry	4
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CHEMICAL ENGINEERING AND MATERIALS SCIENCE COURSES **UNITS**

CHE 487	Nanotechnology and Nanoscale Engineering through Chemical Processes	3
CHE 491	Nanotechnology Research for Undergraduates (two semesters)	2-2
MASC 350	Nanostructured Materials: Design, Synthesis, and Processing	3

CHE Technical Elective

CHE 405	Applications of Probability and Statistics for Chemical Engineers, or	3
CHE 485	Computer-Aided Chemical Process Design	

OTHER ENGINEERING COURSES **UNITS***Nano Technical Elective*

EE 438L	Processing for Microelectronics, or	3
CHE 489	Biochemical Engineering, or	
PTE 463L	Introduction to Transport Processes in Porous Media	

Bachelor of Science in Chemical Engineering (Petroleum Engineering)

The requirement for the degree is 133 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in chemical engineering and 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	4
CHEM 430b	Physical Chemistry	

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/Materials Science)

The requirement for the degree is 133 units. A scholarship average of C (2.0) or higher is required in all upper division courses taken in the Departments of Chemical Engineering,

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

CHEMISTRY COURSES **UNITS**

CHEM 322bL	Organic Chemistry, or	
CHEM 430b	Physical Chemistry	4

OTHER CHEMICAL ENGINEERING/MATERIALS SCIENCE COURSES **UNITS**

CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 472	Polymer Science and Engineering	3
CHE 476	Chemical Engineering Materials, or	
MASC 310	Materials Behavior and Processing	3
MASC 350	Nanostructured Materials: Design, Synthesis, and Processing	3

OTHER ENGINEERING COURSES (CHOOSE THREE COURSES) **UNITS***Polymer/Materials Elective Courses*

BME 410	Introduction to Biomaterials and Tissue Engineering	3
CHE 474L	Polymer Science and Engineering Laboratory	3
CHE 475	Physical Properties of Polymers	3
CHE 477	Computer Assisted Polymer Engineering and Manufacturing	3
CHE 487	Nanotechnology and Nanoscale Engineering through Chemical Processes	3
EE 438L	Processing for Microelectronics	3
MASC 440	Materials and the Environment	3

Minor in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 564.

Graduate Degrees

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 either CHE 550ab or CHE 590 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 Mork Family Department of Chemical Engineering and Materials Science office.

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.

Graduate Certificate in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 571.

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*.

CHE 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 105aL or CHEM 115aL.

CHE 330 Chemical Engineering Thermodynamics (3, Fa) Elements of chemical engineering thermodynamics, including generalized correlations of properties of materials, phase behavior, physical and chemical equilibria. *Corequisite:* MATH 226.

CHE 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 105bL or CHEM 115bL; *recommended preparation:* CHE 330.

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

CHE 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.

CHE 410 Introduction to Biomaterials and Tissue Engineering (3, Fa) (Enroll in BME 410)

CHE 442 Chemical Reactor Analysis (3, Fa) Basic concepts of chemical kinetics and chemical reactor design. *Prerequisite:* MATH 245.

CHE 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.

CHE 444aL 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.

CHE 445 Heat Transfer in Chemical Engineering Processes (2) 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.

CHE 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.

CHE 460L Chemical Process Dynamics and Control (3, 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.

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

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

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

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

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

CHE 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 322aL.

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

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

CHE 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 322aL.

CHE 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.

CHE 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.

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

CHE 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.

CHE 487 Nanotechnology and Nanoscale Engineering through Chemical Processes (3) Properties and processing of nanomaterials including polymeric, metallic, and ceramic nanoparticles, composites, colloids, and surfactant self-assembly for templated nanomaterial production. *Prerequisite:* CHEM 105aL or CHEM 115aL or MASC 110L.

CHE 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 320L.

CHE 490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit.

CHE 491 Nanotechnology Research for Undergraduates (2) Independent research in nanotechnology. Research project selected by the student in close consultation with a research mentor. Graded CR/NC. *Prerequisite:* CHE 487.

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

CHE 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.

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

CHE 510 Energy and Process Efficiency (3, Sp) Management and engineering strategies utilized to improve energy efficiency. Open only to graduate students.

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

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

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

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

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

CHE 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.

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

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

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

CHE 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.

CHE 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.

CHE 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.

CHE 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.

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

CHE 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.

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

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

CHE 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.

CHE 611 Stochastic Modeling and Simulation (3) (Enroll in CE 611)

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

CHE 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.

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

Materials Science – Mork Family Department of Chemical Engineering and Materials Science

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Chair: Theodore T. Tsotsis, Ph.D.

Director: Edward Goo, Ph.D.

Faculty

Fluor Early Career Chair in Engineering:
Andrea M. Armani, Ph.D. (*Chemical Engineering, Electrical Engineering*)

M.C. Gill Chair in Composite Materials: Steven R. Nutt, Ph.D. (*Aerospace and Mechanical Engineering*)

Kenneth T. Norris Professor of Engineering:
Anupam Madhukar, Ph.D. (*Physics*)

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Associate Professor: Edward Goo, Ph.D.

Assistant Professor: Andrea Hodge, Ph.D. (*Aerospace and Mechanical Engineering*)

Research Professor: Peter Will, Ph.D. (*Information Sciences Institute*)

Emeritus Professors: Murray Gershenzon, Ph.D. (*Electrical Engineering*); Ronald Salovey, Ph.D.; William G. Spitzer, Ph.D. (*Physics and 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	Nanostructured Materials: Design, Synthesis, and Processing	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: CHE 501; EE 471; MASC 501, MASC 503, MASC 504, MASC 505 and MASC 561. The six 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.

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.

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.

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*.

MASC 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.

MASC 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.

MASC 334L Mechanical Behavior of Materials (3) (Enroll in CE 334L)

MASC 350 Nanostructured Materials: Design, Synthesis, and Processing (3, Sp)

Structure, properties, synthesis, processing and design of metallic, ceramic, polymeric, electronic, photonic, composite, nanophase and biomaterials; nanostructures, micro-fabrication and smart materials. *Prerequisite:* CHEM 105a or CHEM 115a or MASC 110L, PHYS 152.

MASC 437 Fundamentals of Solid State (3)

Atomic theory; wave mechanics; crystal structure; lattice vibrations; elasticity theory; free electron and tight bonding approximations. *Prerequisite:* MASC 110L or EE 338, PHYS 153L, and MATH 445.

MASC 438L Processing for Microelectronics (3) (Enroll in EE 438L)

MASC 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 110L, EE 338.

MASC 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.

MASC 471 Applied Quantum Mechanics for Engineers (3) (Enroll in EE 471)

MASC 472 Polymer Science and Engineering (3) (Enroll in CHE 472)

MASC 475 Physical Properties of Polymers (3) (Enroll in CHE 475)

MASC 476 Chemical Engineering Materials (3) (Enroll in CHE 476)

MASC 499 Special Topics (2-4, max 8)

Course content will be selected each semester to reflect current trends and developments in the field of materials science.

MASC 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.

MASC 502 Advanced Solid State (3, Fa)

Semiconductors, dielectrics and metals, thermoelectric effects, magnetism, magnetic resonance and superconductivity. *Prerequisite:* MASC 501.

MASC 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.

MASC 504 Diffusion and Phase Equilibria (3, Sp)

Phase equilibria; phase diagrams; diffusion; planar defects; nucleation and growth; spinodal decomposition; phase transformation. *Prerequisite:* MASC 503.

MASC 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.

MASC 506 Semiconductor Physics (3, Fa) (Enroll in EE 506)

MASC 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.

MASC 511 Materials Preparation (3) Principles and techniques of materials preparation; purification, crystal growth from liquid and vapor phases, sintering. *Prerequisite:* MASC 504.

MASC 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.

MASC 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.

MASC 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.

MASC 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, electrooxidation, electrochemical reduction, reactive film formation, enzyme electrochemistry.

MASC 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).

MASC 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 536L.) *Recommended preparation:* MASC 505.

MASC 539 Engineering Quantum Mechanics (3) (Enroll in EE 539)

MASC 548 Rheology of Liquids and Solids (3) (Enroll in CHE 548)

MASC 551 Mechanical Behavior of Engineering Materials (3, Sp) Mechanical properties of materials; macroscopic mechanical behavior related to structure and microstructure of the material; elementary dislocation theory related to basic strengthening mechanisms; fatigue and fracture; nanomaterials. *Recommended preparation:* MASC 310.

MASC 559 Creep (3) (Enroll in AME 559)

MASC 560 Fatigue and Fracture (3) (Enroll in AME 560)

MASC 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.

MASC 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.

MASC 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.

MASC 576 Molecular Dynamics Simulations of Materials and Processes (3, Sp) Molecular dynamics method for atomistic simulations of materials and processes, simulations using parallel computing, correlation functions for structural and dynamical properties plus simulation project. *Prerequisite:* MASC 575.

MASC 583 Materials Selection (3) (Enroll in AME 588)

MASC 584 Fracture Mechanics and Mechanisms (3) (Enroll in AME 584)

MASC 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.

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

MASC 598 Materials Science Seminar (1) Seminar in Materials Science research. To be taken only once for graduate credit. Graded CR/NC.

MASC 599 Special Topics (2-4, max 9)

MASC 601 Semiconductor Devices (3) (Enroll in EE 601)

MASC 606 Nonequilibrium Processes in Semiconductors (3, Sp) (Enroll in EE 606)

MASC 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.

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

MASC 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.

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

Petroleum Engineering – Mork Family Department of Chemical Engineering and Materials Science

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Chair: Theodore T. Tsotsis, Ph.D.

Director: Iraj Ershaghi, Ph.D., P.E.

Faculty

Zohrab A. Kaprielian Dean's Chair in Engineering and Chester F. Dolley Chair in Petroleum Engineering; Yannis C. Yortsos, Ph.D.

William M. Keck Professor of Energy Resources: Donald M. Paul, Ph.D.

Omar B. Milligan Chair in Petroleum Engineering: Iraj Ershaghi, Ph.D., P.E.

Gordon S. Marshall Professor in Engineering Technology: Dongxiao Zhang, Ph.D. (Civil and Environmental Engineering)

Assistant Professor: Kristian Jessen, Ph.D.

Lecturers: Stephen Cheung, Ph.D.; Donald Clarke, M.S.; Robert Ehrlich, Ph.D.; Donald G. Hill, Ph.D.; Bradford Pierce, M.S.; Andrei

Popa, Ph.D.; Allan Spivak, Ph.D.; Ke Thia Yao, Ph.D.; Victor M. Ziegler, Ph.D.

Research Professor: Fred Aminzadeh, Ph.D.

Emeritus Professor: Elmer L. Dougherty, Ph.D.

Petroleum Engineering Honor Society: Pi Epsilon Tau

Degree Requirements

Bachelor of Science in Chemical Engineering (Petroleum Engineering)

See the listing under Chemical Engineering, page 595.

Bachelor of Science in Mechanical Engineering (Petroleum Engineering)

See the listing under Aerospace and Mechanical Engineering, page 575.

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

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
		16

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*.

PTE 202x 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.

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

PTE 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 105aL or CHEM 115aL, PHYS 151L, CE 309.

PTE 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.

PTE 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 463L.

PTE 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.

PTE 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 105aL or CHEM 115aL, PHYS 151L.

PTE 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 463L.

PTE 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 464L.

PTE 466 Petroleum Geology (3, Sm) Introductory topics of physical and historical geology will be focused on the components that relate to the formation of oil and gas accumulations.

PTE 490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit.

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

PTE 502 Advanced Reservoir Characterization (3, Irregular) Sources of data for reservoir characterization; cross-disciplinary integration; geologic models; sequence stratigraphic, lithologic, well test and geophysical models; 4-D seismic; compartmentalized and fractured reservoirs; error and risk analysis. Graduate standing in PTE. *Prerequisite:* PTE 411x, PTE 461; *corequisite:* PTE 506.

PTE 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 464L.

PTE 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. *Recommended preparation:* PTE 507.

PTE 511 Advanced Phase Behavior of Petroleum Reservoir Fluids (3, Irregular) From classical thermodynamics to engineering application; equations of state based calculations; PVT experiments; reservoir fluid characterization; PT-flash calculations and stability analysis; compositional grading; transport properties. Open only to graduate students. *Recommended preparation:* CHE 330, MATH 226.

PTE 512 Gas Injection Processes – Analytical Solutions and Analysis (3, Fa) Gas injection and enhanced oil/gas recovery; conservation equations; flow and phase behavior; displacement efficiency; dispersion; method of characteristics; development of multicontact miscibility in multicomponent systems. Open only to graduate students. *Recommended preparation:* CHE 330, MATH 226 and MATH 245 (or similar).

PTE 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.

PTE 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 464L.

PTE 531 Enhanced Oil Recovery (3, 2 years, Sm) Survey of current enhanced oil recovery processes, including water-flooding, miscible displacement, and thermal oil recovery. *Prerequisite:* PTE 464L; *recommended preparation:* PTE 507.

PTE 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.

PTE 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 430a.

PTE 555 Well Completion, Stimulation, and Damage Control (3, Sp) 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.

PTE 572 Geostatistics (3, 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. Graduate standing. *Recommended preparation:* knowledge of statistics.

PTE 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.

PTE 581 Environmental Technology in the Petroleum Industry (3, Irregular) 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. Graduate standing.

PTE 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.

PTE 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.

PTE 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.

PTE 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.

PTE 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.

PTE 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.

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

PTE 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.

PTE 611 Stochastic Modeling and Simulation (3) (Enroll in CE 611)

PTE 690 Directed Research (1-4) Laboratory study of specific problems for candidates for the degree engineer in petroleum engineering. Graded CR/NC.

PTE 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.

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

Civil Engineering – Sonny Astani Department of Civil and Environmental Engineering

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Chair: Jean-Pierre Bardet, Ph.D.

Faculty

Fred Champion Professor of Civil and Environmental Engineering: Constantinos Sioutas, Sc.D.

Gordon S. Marshall Professor in Engineering Technology: Dongxiao Zhang, Ph.D.

Professors: James C. Anderson, Ph.D.*; Jean Pierre Bardet, Ph.D. (*Chair, Director of Environmental 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.; Sami F. Masri, Ph.D. (*Aerospace and Mechanical Engineering*); Najmedin Meshkati, Ph.D., C.P.E. (*Industrial and Systems Engineering*); James Moore, Ph.D. (*Industrial and Systems Engineering; Policy, Planning, and Development*); Massoud Pirbazari, Ph.D. (*Environmental Engineering, Associate Director of Environmental Engineering*); Costas Synolakis, Ph.D. (*Aerospace*

Engineering); Mihailo Trifunac, Ph.D.; Firdaus E. Udwardia, Ph.D. (*Aerospace and Mechanical Engineering*); L. Carter Wellford, Ph.D.; John P. Wilson, Ph.D. (*Geography, College of Letters, Arts and Sciences*); Hung Leung Wong, Ph.D.*; Yan Xiao, Ph.D., P.E.

Associate Professor: Erik A. Johnson, Ph.D. (*Associate Chair*)

Assistant Professors: Burcin Becerik-Gerber, D.Des.; Amy L. Rechenmacher, Ph.D.

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

Research Professors: Craig Taylor, Ph.D.; Maria I. Todorovska, Ph.D.; Dennis E. Williams, Ph.D.

Research Associate Professor: Robert Nigbor, Ph.D., P.E.

Research Assistant Professors: Aggeliki Barberopoulou, Ph.D.; Jose C. Borrero, Ph.D.; John Caffrey, Ph.D.; Philip M. Fine, Ph.D.; Michael D. Geller, Ph.D.; Le Dam Hanh-Griffin, Ph.D.; John A. Kuprenas, D.Eng., P.E.; Katharine Moore, Ph.D.; Zhi Ning, Ph.D.; Andrea Polidori, Ph.D.

Senior Lecturers: Henry M. Koffman, P.E.; Dana Sherman, Esq.

Emeritus Professors: Mihran S. Agbabian, Ph.D., P.E.; George V. Chilingar, 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) Professional Achievement

Graduates will be successful in their chosen field of engineering, compete effectively as problem-solvers in a world of technological change and become leaders in industry, academic or governmental institutions.

(2) Societal Impact

Graduates will make use of their knowledge of global and societal issues, environmental considerations and sustainability objectives to create a safe and healthy world.

(3) Organizational and Team-Building Skills

Graduates will use their organizational abilities, communication skills and strengths in collaborative teamwork to foster a productive and efficient work environment in the organizations with which they are associated.

(4) Professional Development

Graduates will uphold high ethical and professional standards, be active in professional engineering organizations, support the advancement of the practice of engineering and obtain professional licensure.

(5) Continuing Education

Graduates will engage in lifelong learning and be prepared to pursue graduate studies in engineering or other diverse fields such as business, law or medicine.

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 (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 563.

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

GENERAL EDUCATION (SEE PAGE 61)	UNITS
General education* +	20

PRE-MAJOR REQUIREMENTS	UNITS
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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

GEOL 305Lx	Introduction to Engineering Geology, or	
BISC 220L	General Biology: Cell Biology and Physiology	4

MAJOR REQUIREMENTS	UNITS
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ENGR 102	Engineering Freshman Academy	2
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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
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Elective	Civil Engineering	6
Design Kernel***	Civil Engineering Design Kernel Course	6
		131

Total units: 131

*GE Category VI is taken concurrently with WRIT 140.

**Satisfies GE Category III requirement.

***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.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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.

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 (Structural Engineering) (131 Unit Program)

A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as for all courses taken within 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 563.

COMPOSITION/WRITING REQUIREMENTS UNITS

WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61) UNITS

General education* +	20
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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

GEOL 305Lx	Introduction to Engineering Geology	4
		32

MAJOR REQUIREMENTS UNITS*Engineering*

ENGR 102	Engineering Freshman Academy	2
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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 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
<i>Capstone Course</i>		
CE 480	Structural System Design	3
CE 482	Foundation Design	3

Courses from Other Engineering Departments

EE 202L	Linear Circuits, or	
EE 326L	Essentials of Electrical Engineering	4

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MAJOR ELECTIVES UNITS

Elective***	Civil Engineering	3
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Total units: 131

*GE Category VI is taken concurrently with WRIT 140.

**Satisfies GE Category III requirement.

***The civil engineering elective must be selected from the following courses: CE 409a, CE 478.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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) (136 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 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 563.

COMPOSITION/WRITING REQUIREMENT UNITS

WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61) UNITS

General education* +	20
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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

GEOL 305Lx	Introduction to Engineering Geology	4
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MAJOR REQUIREMENTS UNITS*Engineering*

ENGR 102	Engineering Freshman Academy	2
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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 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

MAJOR ELECTIVES	UNITS
Elective**** Civil Engineering	3
Total units:	136

*GE Category VI is taken concurrently with WRIT 140.

**Satisfies GE Category III requirement.

***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.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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 (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 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 563.

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

GENERAL EDUCATION (SEE PAGE 61)	UNITS
General education* +	20

PRE-MAJOR REQUIREMENTS

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

Other Requirement

BISC 220L	General Biology: Cell Biology and Physiology, or	
GEOL 305Lx	Introduction to Engineering Geology	4

MAJOR REQUIREMENTS

ENGR 102	Engineering Freshman Academy	2
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Civil and Environmental Engineering

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
<i>Aerospace and Mechanical Engineering</i>		
AME 310	Engineering Thermodynamics I	3
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MAJOR ELECTIVE	UNITS
Design kernel***	6
Total units:	130

*GE Category VI is taken concurrently with WRIT 140.

**Satisfies GE 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.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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 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 civil engineering. In addition, a minimum grade of C must be earned in each of the following courses: CE 205 and CE 309 or ENE 410. See also common requirements for undergraduate degrees section, page 563.

COMPOSITION/WRITING REQUIREMENT UNITS

WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61) UNITS

General education* +	20
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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
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MAJOR REQUIREMENTS (BOTH TRACKS) UNITS

Engineering

ENGR 102	Engineering Freshman Academy	2
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Civil and Environmental Engineering

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 309	Fluid Mechanics, or	
ENE 410	Environmental Fluid Mechanics	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 428	Air Pollution Fundamentals	3
ENE 486	Design of Solid and Hazardous Waste Engineering Systems	3
		56

MAJOR REQUIREMENTS (TRACK I ONLY) UNITS

Civil and Environmental Engineering

ENE 429	Air Pollution Control	3
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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

Civil and Environmental Engineering

ENE 487	Environmental Biotechnology and Bioremediation	3
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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

*GE Category VI is taken concurrently with WRIT 140.

**Satisfies GE Category III requirement.

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

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

Minor in Environmental Engineering

See listing on page 617.

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, architecture, environmental studies, and other areas; and a unique opportunity for professional focus to students in the USC College.

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, architecture 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, MATH 208, PPD 404x, PSYC 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, or	
CE 469	Sustainability, or	
CE 470	Building Information Modeling and Integrated Practice	3
<i>Theme Requirement: Two courses, both from Theme 1 or Theme 2 or Theme 3</i>		
<i>Theme 1</i>		
PPD 358	Urban and Regional Economics	4
PPD 362	Real Estate Fundamentals for Planning and Development	4
<i>Theme 2</i>		
FBE 400x	Introduction to Real Estate Finance and Development	4
FBE 466	Management of Real Estate Development: Feasibility Studies	4
<i>Theme 3</i>		
PPD 357	Government and Business	4
PPD 435	Analyzing Real Estate Markets for Planning and Development	4
		17

ELECTIVES (SELECT ONE)		UNITS
CE 404	Business and Intellectual Property Law for Engineers	3
CE 412	Contracts and Specifications	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. Students are advised to take CE 460 and CE 461 before taking CE 462. Students electing PPD 437 must have completed PPD 358.

Minor in Engineering Technology Commercialization

See listing under the Special Educational Opportunities section, page 564.

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 engineering; 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. Students pursuing this program will choose between the following special options: general, earthquake engineering, structural mechanics, water resources or ocean and coastal 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 881.

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	Air Pollution Management: Exposure, Health Effects and Risk	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	Particulate Air Pollutants: Properties/Behavior/Measurement	3

BUSINESS COMMUNICATION/MANAGEMENT AND ORGANIZATION ELECTIVE (CHOOSE ONE)

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

BUSINESS ADMINISTRATION AND ENTREPRENEURSHIP/MANAGEMENT AND ORGANIZATION ELECTIVE (CHOOSE ONE)

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 interdisciplinary degree program offered jointly by the Department of Civil and Environmental Engineering and the USC School of Policy, Planning, and Development. A single application is made to the Department of Civil and Environmental 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. The Master of Construction Management also includes courses from the Marshall School of Business.

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 3
GSBA 510	Accounting Concepts and Financial Reporting 3
CE 556	Project Controls – Budgeting and Estimating 3
CE 566	Project Controls – Planning and Scheduling 3

TRACK REQUIREMENT: TWO COURSES, BOTH FROM TRACK 1, TRACK 2, TRACK 3 OR TRACK 4 UNITS

<i>Track 1: Real Estate Markets Track</i>		
RED 509	Market Analysis for Real Estate, or	
RED 598	Real Estate Product Development	4
RED 542	Finance of Real Estate Development	3
<i>Track 2: Finance Track (if Track 2 is chosen, GSBA 548 must be taken as a prerequisite)</i>		
FBE 570	Advanced Topics in Real Estate Finance	3
FBE 591	Real Estate Finance and Investment	3
<i>Track 3: Real Estate Development Track (If Track 3 is chosen, GSBA 548 must be taken as a prerequisite)</i>		
FBE 565	Economics of Urban Land Use: Feasibility Studies	3
FBE 566	Advanced Topics in Real Estate Finance	3
<i>Track 4: Architecture, Engineering and Construction (AEC) Technology Track</i>		
CE 470	Building Information Modeling and Integrated Practice	3
CE 469	Sustainability, or	
CE 570	Building Information Modeling for Collaborative Construction	3
	Additional advisor approved technical and advanced electives	10-11
	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 and Environmental 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 June 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 to take 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 on joint degree programs, page 881.

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	UNITS
<i>Structural Analysis (two courses, 6 units)</i>	
CE 459	Introduction to Structural Dynamics 3
CE 529a	Finite Element Analysis 3
CE 540	Limit Analysis of Structures 3
<i>Structural Design (four courses, 12 units)</i>	
CE 528	Seismic Analysis and Design of Reinforced Concrete Bridges 3
CE 536	Structural Design for Dynamic Loads 3
CE 537	Advanced Reinforced Concrete Design 3
CE 538	Prestressed Concrete Design 3
CE 539	Advanced Steel Structures 3
<i>Design Project (one course, 3 units)</i>	
CE 549	Building Design Project, or
CE 590	Directed Research 3

Elective Courses (three courses, 9 units)

CE 457	Reinforced Concrete Design	3
CE 458	Theory of Structures II	3
CE 478	Timber and Masonry Design	3
CE 480	Structural Systems Design	3
CE 482	Foundation Design	3
CE 488	Computer Applications in Structural Analysis and Design	3
CE 501	Functions of the Constructor	3
CE 525b	Engineering Analysis	3
CE 533	Geotechnical Earthquake Engineering	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, page 566.

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

Graduate Certificate in Engineering Technology Commercialization

See listing under the Special Educational Opportunities section, page 571.

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 contemporary high level programming language.

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.

The courses taken for the certificate may be applied later to the Master of Science in Civil Engineering, transportation option.

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 471	Principles of Transportation Engineering, or	
CE 519	Transportation Engineering	3
CE 583	Design of Transportation Facilities, or	
CE 585	Traffic Engineering and Control	3
ISE 515	Engineering Project Management	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*.

CE 106 Design and Planning of Civil Engineering Systems (2, Fa) 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.

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

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

CE 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.

CE 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 151L.

CE 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.

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

CE 225 Mechanics of Deformable Bodies

(3, Sp) 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.

CE 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.

CE 325 Dynamics (3, Sp) 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.

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

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

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

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

CE 404 Business and Intellectual Property Law for Engineers (3, Fa) An examination of legal issues confronting the professional engineer. Topics include the legal system, contracts, risk management, forms of doing business, capital formation and intellectual property rights. Upper division standing.

CE 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 325.

CE 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.

CE 409aL Computer-Aided Design (3-3)

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.

CE 412 Construction Law and the Property Development Process (3, Sp) 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.

CE 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.

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

CE 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, multi-purpose water resources projects. *Prerequisite:* CE 309 or ENE 410.

CE 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 105aL or CHEM 115aL; *corequisite:* CE 408 or CHE 405; CE 309 or ENE 410.

CE 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 207L, CE 225; *corequisite:* CE 358.

CE 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 207L, CE 225; *corequisite:* CE 358.

CE 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 150L and AME 353.

CE 459 Introduction to Structural Dynamics (3, Fa) 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.

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

CE 461 General Construction Estimating (3, Fa) Theory of estimating. Quantity surveying; unit cost synthesis and analysis. Bid organization and preparation; competitive simulations and exercises.

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

CE 463L Water Chemistry and Analysis (3, Sp) 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 105b or CHEM 115bL.

CE 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.

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

CE 466 Design of Free-Surface Hydraulic Systems (3, Sp) 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.

CE 467L Geotechnical Engineering (4, Sp) 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.

CE 468L Experimental Soil Mechanics (3)

Laboratory testing of soils and computer processing of experimental measurements, soil classification, compaction tests, permeability tests, unconfined compression, direct shear, consolidation, triaxial tests. *Prerequisite:* CE 464.

CE 469 Sustainability (3, FaSp) Leadership in Energy and Environmental Design (LEED); Green Building strategies; Carbon Footprinting; calculating the embodied energy of building materials; cyclical processes in design and construction.

CE 470 Building Information Modeling and Integrated Practice (3, Fa) Building Information Modeling, current BIM technologies; coordination of design and construction; information management throughout building lifecycle; project delivery systems and technologies for integrated practice.

CE 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.

CE 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.

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

CE 476 Design of Pressurized Hydraulic Systems (3, Sp) 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.

CE 477 Civil Infrastructure Information Systems (3) 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.

CE 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.

CE 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 467L, CE 473, CE 482.

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

CE 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 451, CE 463L, CE 473.

CE 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 phosphorus removal, carbon adsorption. *Prerequisite:* CE 451, CE 463L, CE 473.

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

CE 490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit.

CE 495 Seminars in Civil Engineering (1, FaSp) Information necessary for successful transition to engineering practice with emphasis on substantive engineering topics, employee rights and responsibilities, communication skills, ethic and lifelong learning. Graded Credit/No Credit. Open only to upper division engineering majors.

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

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

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

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

CE 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.

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

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

CE 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.

CE 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.

CE 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.

CE 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.

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

CE 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 463L.

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

CE 515 Sustainable Infrastructure Systems (3) Explores broad issues and mitigation measures involved in the analysis and design of complex, uncertain, interacting infrastructure systems needing to be resilient and sustainable.

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

CE 517 Industrial and Hazardous Waste Treatment and Disposal (3, 2 years, 5m) 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 463L.

CE 518 Carbon Capture and Sequestration (3) The needs for carbon capture and sequestration (CCS) and systematic introduction to CCS technologies. Main topics include: introduction to global change, world energy consumption, greenhouse gases control, carbon capture and separation, and carbon sequestration.

CE 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.

CE 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 530a.

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

CE 523 Process Kinetics and Dynamics in Environmental Engineering (3) Concepts and application of processes that affect water quality in natural and engineered systems. Major processes include: flocculation, sedimentation, filtration, oxidation, adsorption and membrane processes. *Prerequisite:* CE 453 or CE 463L.

CE 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.

CE 528 Seismic Analysis and Design of Reinforced Concrete Bridges (3, Sp) 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.

CE 529ab Finite Element Analysis (a: 3, Fa; b: 3, Sp) 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.

CE 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.

CE 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.

CE 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.

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

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

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

CE 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 541a.

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

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

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

CE 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.

CE 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 541a.

CE 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.

CE 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.

CE 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.

CE 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:* CE 529a. *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 545a.

CE 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.

CE 549 Building Design Project (3, Sp) 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 459 or CE 541a, CE 458 or CE 529a, CE 537; *corequisite:* CE 539.

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

CE 551 Computer-Aided Engineering Project (3) 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.

CE 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.

CE 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.

CE 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.

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

CE 556 Project Controls – Budgeting and Estimating (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. (Duplicates credit in the former CE 556a.) Open only to graduate students in engineering, architecture, business, or urban and regional planning.

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

CE 558 International Construction and Engineering (3, Sp) 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.

CE 559 Strategic Planning in Construction Engineering (3, Sp) 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.

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

CE 561 Uncertainty Quantification (3) Methods of quantifying uncertainty in civil engineering and related fields. Basic uncertainty modeling; advanced topics such as reliability analysis, Bayesian updating, random processes, random fields.

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

CE 563 Chemistry and Biology of Natural Waters (3) 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.

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

CE 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.

CE 566 Project Controls – Planning and Scheduling (3, FaSp) Fundamental principles and practices of planning, CPM scheduling, and resource management. Development of project schedules using CPM theory applied to current and emerging software applications. (Duplicates credit in the former CE 556b.) Open only to graduate students in engineering, architecture, business, or urban and regional planning. *Recommended preparation:* CE 556.

CE 570 Building Information Modeling for Collaborative Construction (3, Sp) Multi-disciplinary and geographically distributed virtual project teams used to simulate engineering and construction problems for projects selected in collaboration with industry partners. Open only to Master's and Doctoral students. *Prerequisite:* CE 470; *recommended preparation:* CE 556, CE 566.

CE 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.

CE 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.

CE 580 Law and Finance for Engineering Innovation (3) (Enroll in ISE 565)

CE 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.

CE 585 Traffic Engineering and Control (3, Sp) 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.

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

CE 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.

CE 589 Port Engineering: Planning and Operations (3, Fa) 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.

CE 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.

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

CE 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.

CE 611 Stochastic Modeling and Simulation (3) Stochastic methods for modeling and simulating physical, chemical and biological processes. Topics include: Stochastic partial differential equations, Monte Carlo simulations, moment equation methods, stochastic expansions. Open only to graduate students.

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

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

CE 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.

CE 645 Uncertainty Modeling and Stochastic Optimization (3) Introduction to the mathematical foundations, numerical algorithms, and computational tools necessary for solving problems of optimization under uncertainty. Open only to graduate students.

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

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

CE 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.

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

Environmental Engineering – Sonny Astani Department of Civil and Environmental Engineering

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Engineering); Jiin-Jen Lee, Ph.D., P.E. (*Civil Engineering*)*; Massoud Pirbazari, Ph.D. (*Civil Engineering*)

*Recipient of university-wide or school teaching award.

Degree Requirements

Educational Program Objectives

Environmental engineers are the technical professionals who identify and mitigate environmental damage. Environmental engineers provide safe drinking water, treat and properly dispose of wastes, maintain air quality, control water pollution and remediate sites contaminated by spills of hazardous substances. They monitor the quality of the air, water and land

and develop improved means to protect the environment.

The undergraduate programs in environmental engineering have the following objectives:

(1) *Professional Achievement*

Graduates will be successful in their chosen field of engineering, compete effectively as problem solvers in a world of technological

change, and become leaders in industry, academic or governmental institutions.

(2) *Societal Impact*

Graduates will make use of their knowledge of global and societal issues, environmental considerations and sustainability objectives to create a safe and healthy world.

(3) *Organizational and Team-Building Skills*
Graduates will use their organizational abilities, communication skills and strengths in collaborative teamwork to foster a productive and efficient work environment in the organizations with which they are associated.

(4) *Professional Development*
Graduates will uphold high ethical and professional standards, be active in professional engineering organizations, support the advancement of the practice of engineering and obtain professional licensure.

(5) *Continuing Education*
Graduates will engage in lifelong learning, and be prepared to pursue graduate studies in engineering or other diverse fields such as business, law or medicine.

Bachelor of Science in Environmental Engineering

See listing on page 607, Civil Engineering.

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	Introduction to Applied Environmental Science and Engineering	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 607.

Master of Science in Environmental Engineering

See listing under Civil Engineering on page 609.

Master of Engineering in Environmental Quality Management

See listing under Civil Engineering on page 609.

Engineer in Environmental Engineering

Requirements for the Engineer in Environmental Engineering are the same as set forth in the general requirements. See page 569.

Ph.D. in Civil Engineering (Environmental Engineering)

See listing under Civil Engineering on page 611.

Sustainable Cities Graduate Certificate

See the listing in the Interdisciplinary Programs section on page 112.

Courses of Instruction

ENVIRONMENTAL ENGINEERING (ENE)

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

ENE 201 Introduction to Applied Environmental Science and Engineering (4) 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.

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

ENE 400 Environmental Engineering Principles (3, Sp) Analysis of water, air, and land pollution, including hazardous waste and engineering of mitigation measures. Water and waste water treatment analysis. *Prerequisite:* CHEM 105bL or CHEM 115bL; MATH 226; PHYS 152L.

ENE 410 Environmental Fluid Mechanics (3) 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.

ENE 428 Air Pollution Fundamentals (3, Fa) Air pollution effects on man, vegetation, materials; pollutant sampling and analysis; air quality standards and criteria; meteorological factors and dispersion modeling. *Prerequisite:* ENE 400.

ENE 429 Air Pollution Control (3, Sp) 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.

ENE 443 Environmental Chemistry (3) (Enroll in CE 443)

ENE 453 Water Quality Control (3) (Enroll in CE 453)

ENE 463L Water Chemistry and Analysis (3) (Enroll in CE 463L)

ENE 465 Water Supply and Sewerage System Design (3) (Enroll in CE 465)

ENE 486 Design of Solid and Hazardous Waste Engineering Systems (3, Fa) Engineering design of solid and hazardous waste facilities such as waste minimization, secured landfill, and hazardous waste treatment. *Prerequisite:* ENE 400.

ENE 487 Environmental Biotechnology and Bioremediation (3) 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 210L, BISC 320L.

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

ENE 502 Environmental and Regulatory Compliance (3) Federal and state environmental laws; environmental impact assessment techniques; permitting for industrial facility construction and operation. *Prerequisite:* graduate standing.

ENE 503 Microbiology for Environmental Engineers (3) (Enroll in CE 503)

ENE 504 Solid Waste Management (3) (Enroll in CE 504)

ENE 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.

ENE 506 Ecology for Environmental Engineers (3, Fa) The role of environmental engineering in maintaining stability of freshwater, marine, and terrestrial ecosystems; macroscopic plant and animal forms as indicators of water quality.

ENE 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.

ENE 513L Instrumental Methods for Environmental Analysis (3) (Enroll in CE 513L)

ENE 514ab Advanced Sanitary Engineering Design (3-3) (Enroll in CE 514ab)

ENE 516 Hazardous Waste Management (3) Standards and regulations for the management of hazardous waste: identification, transportation, monitoring, storage, treatment, and disposal practices.

ENE 517 Industrial and Hazardous Waste Treatment and Disposal (3) (Enroll in CE 517)

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

ENE 523 Process Kinetics and Dynamics in Environmental Engineering (3) (Enroll in CE 523)

ENE 526 Particulate Air Pollutants: Properties/Behavior/Measurement (3) 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.

ENE 535 Air Pollution Management: Exposure, Health Effects and Risk (3, Sp) Pollutant sampling; occupational, community, and personal exposures; receptor modeling; data analysis; health effects of air pollutants.

ENE 553 Chemical and Biological Processes in Environmental Engineering (3) (Enroll in CE 553)

ENE 560 Environmental Aspects of Oil and Gas Production (3) Environmental aspects of drilling for and producing oil and gas, and the necessary safety practices. Attention is given to the urban areas.

ENE 563 Chemistry and Biology of Natural Waters (3) (Enroll in CE 563)

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

ENE 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.

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

ENE 596 Chemical Reactions in the Atmosphere (3, Fa) Chemical reactions and scavenging processes important in urban air pollution. Effects of solar irradiation on vehicle exhaust gases, oxides of nitrogen and sulfur.

ENE 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.

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

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.

COMPOSITION/WRITING REQUIREMENTS		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
GENERAL EDUCATION (SEE PAGE 61)		UNITS
General education* +		20
ENGINEERING		UNITS
ENGR 102	Freshman Academy	2
PRE-MAJOR REQUIREMENTS		UNITS
<i>Math</i>		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Differential Equations	4
MATH 226	Calculus III	4
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science	3

Physics

PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Science elective***		4

MAJOR REQUIREMENTS

UNITS

Computer Science

CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	3
CSCI 200	Object-Oriented Programming	3
CSCI 201L	Principles of Software Development	3
CSCI 271	Discrete Methods in Computer Science	3
CSCI 303	Design and Analysis of Algorithms	3
CSCI 377	Introduction to Software Engineering	3
CSCI 402	Operating Systems	3

Electrical Engineering

EE 101	Introduction to Digital Logic	3
EE 106L	Introduction to Computer Engineering/Computer Science	2
EE 201L	Introduction to Digital Circuits	4
EE 328Lx	Circuits and Electronics for Computer Engineers	4
EE 357	Basic Organization of Computer Systems	3
EE 454L	Introduction to Systems Using Microprocessors	4
EE 457	Computer Systems Organization	3

Engineering Economy/Business
Elective +

3-4

*Senior Design Project*CSCI 477ab Design and Construction
of Large Software
Systems, or

2-2

EE 459L Embedded Systems
Design Laboratory

3

Electives

Technical elective ++

12

Free elective

1-3

Total units:

128

*GE Category VI is taken concurrently with WRIT 140.

**Satisfies GE Category III requirement.

***Any course in physics, biology or chemistry beyond the basic science requirement or in another scientific discipline. See advisor for list of approved courses.

+Engineering Economy/Business Elective (1 course)
Applicable courses include: BUAD 301, BAEP 450x,
ISE 460

++Technical Electives (4 courses)

Applicable courses include: CSCI 300, CSCI 351,
CSCI 445, CSCI 459, CSCI 460, CSCI 464, CSCI
477ab, CSCI 480, CSCI 485, CSCI 486, CSCI 490x,
CSCI 491ab, CSCI 499; EE 450, EE 459L, EE 465,
EE 477L, EE 490x, EE 499; MATH 458. Students may
also choose one advisor-approved course from the
300- and 400-level ITP offerings. Other courses may
be applicable; please see an advisor for approval.

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 in computer engineering and computer science. No more than three courses (maximum 12 units) may be counted at the 400 level – at least 18 advisor-approved units must be taken at the 500 or 600 level.

All applicants must have taken the entrance requirement courses (or equivalent in other institutions) in order to be admitted to the program. Entrance requirement course credit cannot be applied toward the degree. A fundamental course may be waived by taking a placement exam. In case a placement exam is not offered, a fundamental course may be waived by a designated faculty member. At least 18 units must be taken at the 500-level or above. At least 18 units must be taken in electrical engineering, 15 of which must be taken at USC. Units taken outside of electrical engineering or computer science must be approved in advance by a computer engineering advisor and must be substantive in content and related to the degree objective. Up to 3 units of Directed Research (EE 590) with a computer engineering

faculty member may be applied toward the degree.

ENTRANCE REQUIREMENT COURSES		UNITS
CSCI 455x	Introduction to Programming Systems Design	4
EE 357	Basic Organization of Computer Systems	3

Students must take or waive all four of the following fundamental courses (with the option of EE 450 or EE 465):

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

Students must take at least two of the following core courses (with the option of EE 550 or EE 555):

CORE COURSES		UNITS
EE 550	Design and Analysis of Computer Communication Networks, or Broadband Network Architectures	3
EE 555	Computer Systems Architecture	3
EE 557	Computer Systems Architecture	3
EE 577a	VLSI System Design	3

Students must take at least 6 units from the following list of elective courses (cannot overlap with the core courses):

Computer Science: CSCI 545, CSCI 546, CSCI 547, CSCI 551, CSCI 555, CSCI 558L, CSCI 561, CSCI 565, CSCI 570, CSCI 584, CSCI 585, CSCI 595

Electrical Engineering: EE 532, EE 536ab, EE 549, EE 550, EE 552, EE 554, EE 555, EE 557, EE 558, EE 560, EE 577ab, EE 579, EE 630, EE 650, EE 652, EE 653, EE 657, EE 658, EE 659, EE 677, EE 680, EE 681

A minimum grade point average of 3.0 (A = 4.0) must be earned on all course work applied toward the master's degree in computer engineering. This average must also be achieved on all 400-level and above course work attempted at USC beyond the bachelor's degree. Transfer units which count as credit (CR) toward the master's degree are not computed in the grade point average. All other Viterbi School of Engineering requirements for the Master of Science apply.

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.

COURSE REQUIREMENTS	UNITS				
The following course work must be completed; these courses can be included in the 60-unit course work requirement:		MATH 410	Fundamental Concepts of Modern Algebra, or		<i>Systems Area Courses</i>
		MATH 425a	Fundamental Concepts of Analysis	4	CSCI 551 Computer Communications
		MATH 432	Applied Combinatorics, or		CSCI 555 Advanced Operating Systems
		MATH 533	Combinatorial Analysis and Algebra	4	CSCI 561 Foundations of Artificial Intelligence
Take two courses from theory area and four courses from the other three areas (hardware, software and systems), including at least one course from each area to total six courses.		<i>Hardware Area Courses</i>			EE 543a Digital Control Systems
		EE 536a	Mixed Signal Integrated Circuit Design	3	EE 554 Real Time Computer Systems
<i>Theory Area Courses</i>		EE 552	Asynchronous VLSI Design	3	EE 550 Design and Analysis of Computer Communication Networks, or
CSCI 570 Analysis of Algorithms	3	EE 557	Computer Systems Architecture	3	EE 555 Broadband Network Architectures
EE 465 Probabilistic Methods in Computer Systems Modeling, or		<i>Software Area Courses</i>			EE 569 Introduction to Digital Image Processing
EE 549 Queuing Theory for Performance Modeling	3	CSCI 565	Compiler Design, or		
EE 562a Random Processes in Engineering	3	CSCI 595	Advanced Compiler Design	4	
EE 565a Information Theory	3	CSCI 577a	Software Engineering	4	
		CSCI 585	Database Systems	3	

Computer Science

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

Chair and Seeley G. Mudd Professor of Engineering: Shanghua Teng, Ph.D.

Faculty

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

Robert G. & Mary G. Lane Early Career Chair: David Kempe, Ph.D.

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

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

Charles Lee Powell Chair in Engineering: Viktor Prasanna, Ph.D.

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

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

TRW Professor of Software Engineering: Barry Boehm, 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*); Ramesh Govindan, Ph.D.; Ellis Horowitz, Ph.D. (*Electrical Engineering*); Ming-Deh Huang, Ph.D.; Maja Matarić, Ph.D. (*Neuroscience Center*); Dennis McLeod, Ph.D.; Gerard Medioni, Ph.D. (*Electrical Engineering*); Aiichiro Nakano, Ph.D. (*Biomedical Engineering, Materials Science, Physics*); Ulrich Neumann, Ph.D. (*Electrical Engineering*); Ramakant Nevatia, Ph.D. (*Electrical Engineering*); Aristides Requicha, Ph.D. (*Electrical Engineering*); Paul Rosenbloom, Ph.D.; Cyrus Shahabi, Ph.D.; Gaurav Sukhatme, Ph.D. (*Electrical Engineering*); Milind Tambe, Ph.D.; Shanghua Teng, Ph.D.

Associate Professors: Shahram Ghandeharizadeh, Ph.D.; Leana Golubchik, Ph.D. (*Electrical Engineering*); Laurent Itti, Ph.D.; Sven Koenig, Ph.D.; Neno Medvidovic, Ph.D.; Stefan Schaal, Ph.D. (*Neuroscience Center*)

Assistant Professors: Jernej Barbic, Ph.D.; William GJ Halfond, Ph.D.; David Kempe, Ph.D.; Fei Sha, Ph.D.

Joint Professors: 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*); Carl Kesselman, Ph.D. (*Industrial and Systems Engineering*); Bhaskar Krishnamachari, Ph.D. (*Electrical Engineering*); C-C Jay Kuo, Ph.D. (*Signal and Image Processing*); Stephen Lu, Ph.D. (*Industrial and Systems Engineering*); Shri Narayanan, Ph.D. (*Electrical Engineering*); Fernando Ordonez, Ph.D. (*Industrial and Systems Engineering*); Viktor Prasanna, Ph.D. (*Electrical Engineering*); Konstantinos Psounis, Ph.D.; C.S. Raghavendra, Ph.D. (*Electrical Engineering*); Irving Reed, Ph.D. (*Electrical Engineering*); Boris Rozovsky, Ph.D. (*Mathematics*); Nicolas Schweighofer, Ph.D. (*Biokinesiology and Physical Therapy*); Francisco Valero-Cuevas (*Biomedical Engineering*); Priya Vashishta, Ph.D. (*Material Science, Physics*); Michael Waterman, Ph.D. (*Mathematics*); Richard Weinberg, Ph.D. (*Cinematic Arts*); John Wilson, Ph.D. (*Geography*)

Adjunct Professors: Michael Carey, Ph.D., Danny Cohen, Ph.D.; Rick Selby, Ph.D.; Sethu Vijayakumar, Ph.D.

Adjunct Associate Professors: Steve Chien, Ph.D.; Mary Hall, Ph.D.; Larry Matthies, Ph.D.; Zhengyou Zhang, Ph.D.

Adjunct Assistant Professors: Aude Billard, Ph.D.; Alexander Egyed, Ph.D.; Andrew Howard, Ph.D.; Auke Ijspeert, Ph.D.; Steve Jacobs, Ph.D.; Marcelo Kallmann, Ph.D.; Sofus Macskassy, Ph.D.; Xin Wang, Ph.D.

Research Professors: Randall Hill, Ph.D.; Jerry Hobbs, Ph.D.; Carl Kesselman, Ph.D.; Craig Knoblock, Ph.D.; Herbert Schorr, Ph.D.; William Swartout, Ph.D.

Research Associate Professors: Paul Debevec, Ph.D.; Ewa Deelman, Ph.D.; Yolanda Gil, Ph.D.; Jonathan Gratch, Ph.D.; John Heidemann, Ph.D.; Eduard Hovy, Ph.D.; Kevin Knight, Ph.D.; Robert Lucas, Ph.D.; Daniel Marcu, Ph.D.; Stacey Marsella, Ph.D.;

Robert Neches, Ph.D.; Clifford Neuman, Ph.D.; Wei-Min Shen, Ph.D.; Joseph Touch, Ph.D.

Research Assistant Professors: Jose Luis Ambite, Ph.D.; Yu-Han Chang, Ph.D.; Ann L. Chervenak, Ph.D.; David Chiang, Ph.D.; Young Cho, Ph.D.; Pedro Diniz, Ph.D.; Alexandre Francois, Ph.D.; Andrew Gordon, Ph.D.; Jihie Kim, Ph.D.; Kristina Lerman, Ph.D.; Rajiv Maheswaran, Ph.D.; Louis-Philippe Morency, Ph.D.; Patrick Pantel, Ph.D.; Pieter Peers, Ph.D.; Pedro Szekely, Ph.D.; David Traum, Ph.D.; Wei Ye, Ph.D.; Suyu You, Ph.D.

Lecturers: Claire Bono; William Cheng, Ph.D.; St. John Colon, M.F.A.; Michael Crowley, Ph.D. (*Senior Lecturer*); Scott Easley, B.A.; Massoud Ghým-Khah, Ed.D.; Parag Havaladar, Ph.D.; Krishnamurthy Narayanaswamy, Ph.D.; Farid Parvini, Ph.D.; Saty Raghavachary, Ph.D.; Shawn Shamsian, Ph.D.; David Wilczynski, Ph.D.; Michael Zyda, Ph.D. (*Professor of Engineering Practice*)

Emeritus Professor: George Bekey, Ph.D. (*Electrical Engineering, Biomedical Engineering*)

Bachelor of Science

Educational Program Objectives

(1) Technical Competence

Graduates have solved problems encountered in modern practice using the mathematics skills and knowledge about computer hardware and software learned at the university.

Graduates have worked on projects in which they were required to model, analyze, design and experimentally evaluate components or systems to achieve desired technical specifications subject to the reality of economic constraints.

(2) Professional Development

Graduates have followed a career path for which they have been trained either through suitable employment or graduate studies.

Graduates have adapted or extended their professional skills in order to compete effectively in a world of rapid technological change.

Graduates have moved into fields with strong information technology components, such as business, law, cinema and music, through graduate-level studies and the process of life-long learning.

(3) Citizenship in the Global Community

Graduates have shown the capabilities and communication skills necessary to function effectively either as individuals, members or leaders of multidisciplinary teams in a diverse global economy.

Graduates have shown 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 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 3 to 5 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 Viterbi School of Engineering; however, the Bachelor of Science degree with a major in computer science is awarded through the USC College. Candidates must complete general education requirements; see pages 61 and 241.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 140*	Writing and Critical Reasoning	4
WRIT 340**	Advanced Writing	3
GENERAL EDUCATION (SEE PAGE 61)		UNITS
General education* +		20
PRE-MAJOR REQUIREMENTS		UNITS
<i>Math Requirement</i>		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Differential Equations	4

MATH 226	Calculus III	4
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science	3

Basic Science

One of the following two course sequences:
BISC 120L*** and BISC 220L, or
CHEM 105aLbL***, or
PHYS 151L*** and PHYS 152L

Other Requirements

Science elective****	4
Foreign language	12

MAJOR REQUIREMENTS		UNITS
<i>Engineering</i>		
ENGR 102	Engineering Freshman Academy	2
<i>Computer Science</i>		
CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	3
CSCI 200L	Object Oriented Programming	3
CSCI 201L	Principles of Software Development	3
CSCI 271	Discrete Methods in Computer Science	3
CSCI 303	Design and Analysis of Algorithms	3
CSCI 377	Introduction to Software Engineering	3
CSCI 402x	Operating Systems	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2

Electrical Engineering

EE 101	Introduction to Digital Logic	3
EE 106Lx	Introduction to Computer Engineering/Computer Science	2
EE 201L	Introduction to Digital Circuits	4
EE 357	Basic Organization of Computer Systems	3
	Engineering economy/business elective	3-4
	Free electives	0-1
	Technical electives	12
Total units:		128

*GE Category VI is taken concurrently with WRIT 140.

**WRIT 340 Advanced Writing (Communication for Engineers) is strongly recommended for CSCI majors.

***Satisfies general education requirement.

****Any course in physics, biology or chemistry beyond the basic science requirement or in another scientific discipline. See advisor for a list of approved electives.

†The university allows engineering students to replace GE Category IV with a second course in Categories I, II or VI.

Foreign Language Requirement

Three semesters of a single language and passing the skill level examination in that language or passing the skill level examination in a foreign language.

Technical Electives (four courses)

Applicable courses include: CSCI 300, CSCI 351, CSCI 445, CSCI 459, CSCI 460, CSCI 464, CSCI 480, CSCI 485, CSCI 490x, CSCI 499; 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.

Engineering Economy/Business Elective (one course)

Applicable courses include: BUAD 301, BAEP 450x, ISE 460

Bachelor of Science in Computer Science (Games)

The goal of the B.S. in Computer Science (Games) program is to graduate students with a solid grounding in computer science and a cross-disciplinary background in game development. Topics covered in the cross-disciplinary game development portion of the degree program include game production, visual design for games and interactives,

computer animation, video game programming, game hardware architectures, game engine programming, serious game development, introductory and intermediate game design, and two semester-long final game projects. Students graduating from this program will be capable of engineering next-generation games and simulations and their technologies in the entertainment and serious game fields. Additionally, graduates from this program will be able to further their education in graduate programs in game development and computer science. This degree will be offered by the College of Letters, Arts and Sciences.

Requirements for the B.S. in Computer Science (Games):

COMPUTER SCIENCE AND COMPUTER ENGINEERING (36 UNITS) UNITS

CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	3
CSCI 200	Object-Oriented Programming	3
CSCI 201L	Principles of Software Development	3
CSCI 271	Discrete Methods in Computer Science	3
CSCI 303	Design and Analysis of Algorithms	3
CSCI 377	Introduction to Software Engineering	3
CSCI 402x	Operating Systems	3
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 480	Computer Graphics	3
EE 352L	Computer Organization and Architecture	3
EE 450	Introduction to Computer Networks	3

GAME DEVELOPMENT (40 UNITS) UNITS

CSCI 180	Survey of Digital Games and Their Technologies	3
CSCI 281	Pipelines for Games and Interactives	3
CSCI 486	Serious Games Development	3
CSCI 491abL	Final Game Project	4-2
CTAN 452	Introduction to 3-D Computer Animation	2
CTIN 484L	Intermediate Game Development	2
CTIN 488	Game Design Workshop	4
CTIN 489	Intermediate Game Design Workshop	2
EE 452L	Game Hardware Architectures	3
ITP 280	Video Game Production	4
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4

MATH (11-12 UNITS) UNITS

MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Linear Differential Equations, or Applied Linear Algebra for Engineering	4
EE 241	Applied Linear Algebra for Engineering	3

SCIENCE (4 UNITS) UNITS

PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics	4
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WRITING (7 UNITS) UNITS

WRIT 140	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (20 UNITS) UNITS**

The major will comply with the university general education and diversity requirements.

*General Education requirements total 24 units. However, PHYS 151L also satisfies the GE Category III requirement.

**The foreign language requirement will be waived for students in this program.

TECHNICAL ELECTIVES

Choose a minimum of 6 units from the following:

CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 477ab***	Design and Construction of Large Software Systems	2-2
CSCI 485	File and Database Management	3
CSCI 490x	Directed Research	2-8
CSCI 499	Special Topics	2-4
CTAN 330	Animation Fundamentals	2
CTAN 443L	3-D Animation and Character Design	2
CTIN 401L	Interface Design for Games	2
CTIN 403	Advanced Visual Design for Gamers	2
CTIN 404L	Usability Testing for Games	2
CTIN 405L	Design and Technology for Mobile Experiences	2
CTIN 406L	Sound Design for Games	2
CTIN 458	Business and Management of Games	2
CTIN 459L***	Game Industry Workshop	4
CTIN 462	Critical Theory and Analysis of Games	4
CTIN 463	Anatomy of a Game	4

CTIN 482	Designing Online Multiplayer Game Environments	2
CTIN 483	Introduction to Game Development	4
CTIN 492L	Experimental Game Topics	4
EE 320	Digital Media Basics for Multimedia	3
ENGR 395abc***	Cooperative Education Work Experience (students who take 3 units of Co-op may use it as one technical elective).	1 or 2, max 5
Total units required for degree:		128

Other courses may be eligible subject to advisor approval.

***highly recommended

Note: Students are strongly encouraged to take at least 1 unit of internship

Note: Free elective units: (3-4 units)

Note: If a student chooses MATH 225 (4), then no units of free electives would be needed to complete the degree requirements. If EE 241 (3) is chosen, then the student would require 4 units of free electives.

Bachelor of Science in Computer Science/ Business Administration

The combined Bachelor of Science degree program in computer science/business administration offers qualified students the opportunity to gain an educational foundation in both areas. Students must meet the admission requirements for both the Computer Science department in the Viterbi School of Engineering and the Marshall School of Business. The degree is administered by the Computer Science department.

Students should work with advisors in both the Marshall School and the Viterbi School in making appropriate course selections. A minimum of 135 units is required. A GPA of C (2.0) or higher is required for all upper division course, including any approved substitutes for these courses.

ENGINEERING REQUIREMENTS	UNITS
CSCI 101L	Fundamentals of Computer Programming 3
CSCI 102L	Data Structures 3
CSCI 200	Object-Oriented Programming 3
CSCI 201L	Principles of Software Development 3
CSCI 271	Discrete Methods in Computer Science 3
CSCI 303	Design and Analysis of Algorithms 3

CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 377	Introduction to Software Engineering	3
CSCI 460	Introduction to Artificial Intelligence, or Computer Graphics, or File and Database Management	3
CSCI 480	Computer Graphics, or File and Database Management	3
CSCI 485	File and Database Management	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2
CSCI technical electives (see department for approved list)		6
EE 101	Introduction to Digital Logic	3
EE 201L	Introduction to Digital Circuits	4
ENGR 102	Freshmen Academy Seminar	2
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Linear Differential Equations, or	4
EE 241	Applied Linear Algebra for Engineering	3
Basic science requirements I and II*		4-4
Total engineering units:		65-66

BUSINESS REQUIREMENTS	UNITS	
ACCT 410x	Accounting for Non- Business Majors 4	
BUAD 302	Communication Strategy in Business 4	
BUAD 304	Organizational Behavior 4	
BUAD 306	Business Finance 4	
BUAD 307	Marketing Fundamentals 4	
BUAD 497	Strategic Management 4	
Business Electives 300- or 400-level ACCT, BAEP, non-required BUAD, BUCO, FBE, IOM, MKT or MOR 8		
ECON 251x	Microeconomics for Business 4	
ECON 252x	Macroeconomics for Business 4	
BUAD 310	Applied Business Statistics, or 4	
EE 364	Introduction to Probability and Statistics for Electrical Engineering 3	
Total business units		43-44
Total program units:		108-110

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

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 421, for course requirements.

Bachelor of Science in Computer Engineering and Computer Science

See the listing under Computer Engineering, page 619.

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 Internet.

REQUIRED COURSES

Lower division (12 units)

CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	3
CSCI 200	Object-Oriented Programming	3
CSCI 201L	Principles of Software Development	3

ELECTIVES

12 units selected from the following courses:

CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 377	Introduction to Software Engineering	3
CSCI 445	Introduction to Robotics	4
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2
CSCI 480	Computer Graphics	3
CSCI 485	File and Database Management	3
CSCI 499	Special Topics	2-4

Total: 24 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 cinematic arts 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 Engineering Technology Commercialization

See listing under the Special Educational Opportunities section, page 564.

Minor in 2-D Art for Games

This interdisciplinary minor integrates three major disciplines (fine arts, computer science and interactive media) to develop the 2-D

visual skills necessary to conceptualize and illustrate images for games. For more information, see Roski School of Fine Arts, page 672.

Minor in 3-D Art for Games

The focus of the 3-D Art for Games minor is a trans-disciplinary approach that incorporates

the creative, technological and team-based communication skills necessary to develop 3-D art skills for video games. For more information, see Roski School of Fine Arts, page 672.

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 100. 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, see page 660.

A Master of Science in high performance computing simulations is also offered, see page 627.

Admission and Prerequisites

Admission is determined by the Office of Admission and the Viterbi School of Engineering, 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); and a substantial background in computing constitutes a minimum requirement. Foreign students must earn a satisfactory score on the Test of English as a Foreign Language.

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 earned on all graduate courses completed at USC (400-level and above). Transfer units count as credit (CR) toward the master's degree and are not computed in the grade point average. The required courses are as follows: CSCI 570 and one course from each of the following two categories: *I.* CSCI 551, CSCI 555, CSCI 571, CSCI 577a, CSCI 585, EE 557; *II.* CSCI 545, CSCI 561, CSCI 564, CSCI 574, CSCI 580, CSCI 582. 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 and ENGR 596 may be counted for a maximum of 6 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 6 units from approved courses may be taken at the 400 level in either electrical engineering or computer science; and CSCI 590 and ENGR 596 may be 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, computer security and high performance computing simulations.

Master of Science in Computer Science (Game Development)

The goal of the M.S. in Computer Science (Game Development) program is to graduate students with a core in computer science, an engineering-oriented game development core and a concentration in one of the key research directions in game development infrastructure, cognition and games, immersion and serious games. Infrastructure is researching and developing the software and hardware infrastructure necessary for the development of the future of interactive games and large-scale simulations; massively multiplayer online games (MMOGs) and simulation networks; game engines and tools; instant games; wireless and mobile games and infrastructures; and next generation consoles. Cognition and games is developing theories for modeling and simulating computer characters and story; developing methods for modeling, simulating and displaying human emotion; analyzing large-scale game play; and developing theories for infusing pedagogy with game play. Immersion is researching and developing the technologies to engage the mind of the game player

via sensory stimulation; reading the human emotional state and providing that as an input to the game; and emotionally adaptive game software architectures. Serious games and simulations is developing a theory for the deployment of games and simulations for purposes of education and training, health, public policy and strategic communication; game evaluation; serious game development; and human performance engineering. Students graduating from this program will be capable of engineering next generation games and simulations and their required technologies immediately upon graduation in the entertainment and serious game fields. Additionally, graduates from this program will be able to further their education in graduate programs in game development and computer science. The long-term goal with this M.S. degree is to establish research and development directions that create a science of games and an accompanying archival literature that improves game development for both serious and entertainment purposes.

CSCI (9 UNITS)		UNITS
CSCI 570	Analysis of Algorithms	3
CSCI 580	3-D Computer Graphics and Rendering	3
One of the following:		
CSCI 555	Advanced Operating Systems	3
CSCI 561	Foundations of Artificial Intelligence, or	
CSCI 573	Advanced Artificial Intelligence	3
CSCI 571	Web Technologies	3
CSCI 577a	Software Engineering	4
CSCI 585	Database Systems	3
EE 557	Computer Systems Architecture	3

GAME DEVELOPMENT CORE (11 UNITS)		UNITS
CTIN 488	Game Design Workshop	4
CSCI 522	Game Engine Development	4
EE 452	Game Hardware Architectures	3

PROJECT CLASSES (7 UNITS)		UNITS
CSCI 529ab	Advanced Game Projects	4-3

ELECTIVES		UNITS
Complete two courses from one of the following areas of concentration: Infrastructure; Cognition and Games; Immersion; Serious Games.		

Infrastructure

CSCI 503	Parallel Programming	3
CSCI 520	Computer Animation and Simulation	3
CSCI 522	Game Engine Development	4
CSCI 523	Networked Games	3

CSCI 524	Networked Artificial Intelligence	3
CSCI 526	Advanced Mobile Devices and Game Consoles	3

Cognition and Games

CSCI 524	Networked Artificial Intelligence	3
CSCI 534	Affective Computing	3
CSCI 541	Artificial Intelligence Planning	3
CSCI 543	Software Multiagent Systems	3
CSCI 573	Advanced Artificial Intelligence	3

Immersion

CSCI 520	Computer Animation and Simulation	3
CSCI 523	Networked Games	3
CSCI 537	Immersive Environments	3
CSCI 538	Human Performance Engineering	3
CSCI 574	Computer Vision	3
CSCI 588	Specification and Design of User Interface Software	3
CTAN 502a	Experiments in Stereoscopic Imaging	2
CTIN 488	Intermediate Game Design Workshop	4
EE 619	Advanced Topics in Automatic Speech Recognition	3

Serious Games

CSCI 486	Serious Games Development	3
CSCI 520	Computer Animation and Simulation	3
CSCI 537	Immersive Environments	3
CSCI 538	Human Performance Engineering	3

Other courses may be eligible subject to advisor approval.

Total units: 33

Master of Science in Computer Science (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 (Computer Security)

Completion of this program satisfies all the requirements for the Master of Science in computer science.

REQUIRED COURSES		UNITS
CSCI 530	Security Systems	4
CSCI 531	Applied Cryptography	3
CSCI 551	Computer Communications	3
CSCI 555	Advanced Operating Systems	3
CSCI 570	Analysis of Algorithms	3
CSCI 577a	Software Engineering, or	4
CSCI 578	Software Architectures	3

At least one of the following courses:

CSCI 545	Robotics	3
CSCI 561*	Foundations of Artificial Intelligence	3
CSCI 564	Brain Theory and Artificial Intelligence	3
CSCI 573*	Advanced Artificial Intelligence	3
CSCI 574	Computer Vision	3
CSCI 580	3-D Graphics and Rendering	3
CSCI 582	Geometric Modeling	3

At least two of the following courses:

CSCI 556	Introduction to Cryptography	3
CS 558L	Internetworking and Distributed Systems Laboratory	3
CS 571	Web Technologies	3
CS 585	Database Systems	3
CS 599**	Special Topics	2-4, max 9
CS 694a	Topics in Computer Networks and Distributed Systems	3

Total Units: 28

*CSCI 561 or CSCI 573 is recommended for this specialization. CSCI 573 may be used in place of CSCI 561 to satisfy the requirements for the general M.S. degree.

**Topics must be pre-approved by an advisor. Course must be a minimum of 3 units.

Master of Science in Computer Science (High Performance Computing and Simulations)

Students in the MSCS-HPCS program must satisfy the current core requirements for the Master of Science in computer science and the following elective courses must be included in the program:

REQUIRED CORE COURSE UNITS

CSCI 596*	Scientific Computing and Visualization	3
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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 503	Parallel Programming	3
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 653*	High Performance Computing and Simulations	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	3

Computational Science/Engineering Application Track

AME 535a*	Introduction to Computational Fluid Dynamics, or	3
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
MATH 578a	Computational Molecular Biology	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 (Human Language Technology)

Human Language Technology (HLT) – also known as Computational Linguistics and Natural Language Processing – focuses on the treatment of human languages by computer. This field has experienced unprecedented growth over the past few years, thanks to the Internet and the availability of text online. Since the early 1950s, the computational linguistics research community has developed theories and applications for a wide variety of language uses and languages. Theoretical interests overlap with appropriate areas in linguistics, philosophy, psychology and neuroscience; algorithmic issues pertain to machine learning, mathematics/statistics and information theory in signal processing. Typical applications include Web search, machine translation, speech recognition, automated question answering, text summarization, information extraction (including opinions, facts), analysis and management of electronic bulletin boards and chat rooms, product development tracking, news tracking for intelligence gathering and international commerce, and information gathering for report generation.

To obtain a Master of Science in Computer Science with specialization in Human Language Technology, degree students must satisfy the requirements for the Master of Computer Science. At least 27 units must be completed with the following distribution requirements:

REQUIRED COURSES UNITS

CSCI 544	Natural Language Processing	3
CSCI 562	Empirical Methods in Natural Language Processing	3
CSCI 561*	Foundations of Artificial Intelligence, or	3
CSCI 573	Advanced Artificial Intelligence	3
CSCI 570	Analysis of Algorithms	3
At least one of the following courses:		
CSCI 551	Computer Communications	3
CSCI 555	Advanced Operating Systems	3
CSCI 571	Web Technologies	3
CSCI 577a	Software Engineering	4
CSCI 585	Database Systems	3
EE 557	Computer Systems Architecture	3

*CSCI 561 also satisfies the breadth requirements for the M.S., Computer Science.

COMPUTER SCIENCE ELECTIVES UNITS

It is recommended that the remaining units be satisfied from the following computer science electives:

CSCI 545	Robotics	3
CSCI 564	Brain Theory and Artificial Intelligence	3
CSCI 567	Machine Learning	3
CSCI 580	3-D Graphics and Rendering	3
CSCI 574	Computer Vision	3
CSCI 582	Geometric Modeling	3
CSCI 590	Directed Research (up to 6 units for non-thesis students only)	1-12
CSCI 599	Special Topics (subject to advisor review of the topic)	2-4, max 9

NON-COMPUTER SCIENCE ELECTIVES UNITS

Students may take up to two courses from other departments for credit toward the degree. These courses must either be chosen from the following list, or (with permission from one of the M.S. program directors) appropriate courses from linguistics, mathematical statistics, electrical engineering, neuroscience, philosophy and psychology. Suggested courses include:

EE 519	Speech Recognition and Processing for Multimedia	3
EE 619	Advanced Topics in Automatic Speech Recognition	3
LING 530	Generative Syntax	3
MATH 505a	Applied Probability, or	3
MATH 505b	Applied Probability	3
MATH 541a	Introduction to Mathematical Statistics, or	3
MATH 541b	Introduction to Mathematical Statistics	3

Master of Science in Computer Science (Multimedia and Creative Technologies)

See the listing under Multimedia and Creative Technologies, page 660.

Master of Science in Computer Science (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 six courses: CSCI 503, 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

The school is no longer accepting applicants to this certificate program.

Master of Science in Computer Science (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 and CSCI 545 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.

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. Applicants are expected to have completed the equivalent course work necessary to satisfy the general breadth requirements outlined in the Master's Admissions and Prerequisites section (see page 625). Particular attention is given to the applicant's potential to perform original research in an area of computer science. 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 or no later than his or her fourth semester 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 670 Advanced Analysis of Algorithms, CSCI 581 Logic and its Applications, MATH 501 Numerical Analysis 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.

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.

Graduate Certificate in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 571.

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*.

CSCI 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.

CSCI 102L Data Structures (3, FaSp) Linear lists, strings, arrays, and orthogonal lists; graphs, trees, binary trees, multilinked structures, sorting techniques; dynamic storage allocation; applications. *Prerequisite:* CSCI 101L.

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

CSCI 110 Introduction to Digital Logic (3) (Enroll in EE 101)

CSCI 180 Survey of Digital Games and Their Technologies (3, Fa) Historical, technical, and critical approach to the evolution of computer and video game architectures and game design, from its beginnings to the present day.

CSCI 200L Object-Oriented Programming (3, FaSp) The principles of object-oriented programming are examined using Java. Topics include graphics, graphical user interfaces and multi-threaded programming. (Duplicates credit in the former CSCI 105.) *Prerequisite:* CSCI 102.

CSCI 201L Principles of Software Development (3, FaSp) The object-oriented paradigm for programming-in-the-large (using the C++); UNIX tools for software development; developing window-based applications under X-windows. *Prerequisite:* CSCI 200.

CSCI 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 200.

CSCI 280 Video Game Production (4, FaSpSm) (Enroll in ITP 280)

CSCI 281 Pipelines for Games and Interactives (3, Fa) Explores the aesthetic development/technical implementation necessary to achieve unique, compelling, intuitive visual design in games. Students will develop group visual game design portfolios.

CSCI 300 Introduction to Intelligent Agents Using Science Fiction (3, Fa) Fundamental concepts of intelligent agents and multiagent interactions using science fiction short stories and movie clips; topics include decision theory, game theory, auctions, swarms, teamwork, emotions. *Prerequisite:* CSCI 101L.

CSCI 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.

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

CSCI 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 102L.

CSCI 352L Computer Organization and Architecture (3, Sp) (Enroll in EE 352L)

CSCI 355x Software Design for Engineers (3, Fa) Object-oriented programming techniques, basic data structures, elementary complexity analysis to model, simulate and solve engineering problems. Not available for credit for CSCI, CSGM, CSBA, or CECS majors. *Prerequisite:* EE 150.

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

CSCI 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.

CSCI 380 Video Game Programming (4, FaSpSm) (Enroll in ITP 380)

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

CSCI 402 Operating Systems (3, FaSpSm) Basic issues in concurrency, deadlock control, synchronization scheduling, memory management, protection and access control, inter-process communication, and structured design. Laboratory experiences with Unix-like operating system. *Prerequisite:* CSCI 201L or CSCI 455x; EE 357 or EE 352L.

CSCI 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.

CSCI 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 101L or C language programming.

CSCI 450 Introduction to Computer Networks (3) (Enroll in EE 450)

CSCI 452L Game Hardware Architectures (3, Fa) (Enroll in EE 452L)

CSCI 454L Introduction to Systems Design Using Microprocessors (4) (Enroll in EE 454L)

CSCI 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.

CSCI 457 Computer Systems Organization (3) (Enroll in EE 457)

CSCI 458 Numerical Methods (4) (Enroll in MATH 458)

CSCI 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.

CSCI 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 102L or CSCI 455x.

CSCI 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.

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

CSCI 477ab Design and Construction of Large Software Systems (2-2) Programming methodologies; intra-group and inter-group communication; software lifecycle; software economics. A large software project is a central aspect of the course. (Duplicates credit in the former CSCI 477.) *Prerequisite:* CSCI 201, CSCI 377.

CSCI 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.

CSCI 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.

CSCI 486 Serious Games Development (3, Sp) Develop applications of interactive technology that extend beyond the traditional videogame market: education, health, training, policy exploration, analytics, visualization, simulation, the arts and therapy. *Prerequisite:* CTIN 488; *corequisite:* ITP 485.

CSCI 487 Programming Game Engines (4, FaSp) (Enroll in ITP 485)

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

CSCI 491abL Final Game Project (4-2, FaSp) *a:* Design, iterative prototyping, and development of a first playable level. *Prerequisite:* CSCI 486. *b:* Design, iterative stage 2 prototyping and development of a refined game.

CSCI 495 Senior Project (3) (Enroll in PHYS 495)

CSCI 499 Special Topics (2-4, max 8) Selected topics in computer science.

CSCI 501 Numerical Analysis and Computation (3) (Enroll in MATH 501)

CSCI 502ab Numerical Analysis (3-3) (Enroll in MATH 502ab)

CSCI 503 Parallel Programming (3, Sp) Exploration of parallel programming paradigms, parallel computing architectures, hands-on parallel programming assignments, contemporary and historical examples and their impact, context with parallel algorithms. *Recommended preparation:* CSCI 102 or CSCI 455; EE 452 or EE 457.

CSCI 504ab Numerical Solutions of Ordinary and Partial Differential Equations (3) (Enroll in MATH 504ab)

CSCI 505ab Applied Probability (3-3) (Enroll in MATH 505ab)

CSCI 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.

CSCI 511 Personal Software Process (PSP) and Project (3, Sp) Individual analysis, planning, development and maintenance of a software product or development artifact, using the principles and practices of PSP. Analysis of project's lessons learned.

CSCI 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.

CSCI 521 Optimization: Theory and Algorithms (3, Fa) (Enroll in ISE 520)

CSCI 522 Game Engine Development (4, Fa) The principles of developing game engines targeted at modern PC and game console hardware.

CSCI 523 Networked Games (3, Fa) Design and implementation of networked games, from the origins of the supporting technologies in distributed systems, visual simulations, networked virtual environments, and shipped games. *Recommended preparation:* CSCI 480, CSCI 580 or an equivalent course in graphics.

CSCI 524 Networked Artificial Intelligence (3, Sp) Networked game communication architectures, protocol development, architecting networked game AI clients/services. Character following, knowledge representation and reasoning, dynamic play strategies, search, learning, and planning. *Recommended preparation:* CSCI 480, CSCI 580 or an equivalent course in graphics.

CSCI 526 Advanced Mobile Devices and Game Consoles (3, Sp) Explore the complex engineering process required to design and build a real-time graphics engine to support physical realism on mobile devices. *Recommended preparation:* CSCI 480, CSCI 580 or an equivalent course in graphics.

CSCI 529ab Advanced Game Projects (4-3, FaSp) *a:* Team projects intended to address the multifaceted technical and creative challenges that are inherent to comprehensive game development. *Recommended preparation:* CSCI 522 or CTIN 488. *b:* This course provides students in various areas of game specialization the practice of design, iterative stage 2 prototyping and development of a refined game.

CSCI 530 Security Systems (4, FaSp) 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 402x.

CSCI 531 Applied Cryptography (3, Fa) Intensive overview of cryptography for practitioners, historical perspective on early systems, number theoretic foundations of modern day cryptosystems and basic cryptanalysis.

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

CSCI 534 Affective Computing (3, Sp) Overview of the theory of human emotion, techniques for recognizing and synthesizing emotional behavior, and design application. *Prerequisite:* CSCI 561.

CSCI 536 Linear Programming and Extensions (3, Fa) (Enroll in ISE 536)

CSCI 537 Immersive Environments (3, Sp) Design and implementation of immersive environments, from the origins of the supporting technologies in visual simulation, to interactive 3-D graphics and interfaces, and interactive games. *Prerequisite:* CSCI 580.

CSCI 538 Human Performance Engineering (3) Tools and techniques for addressing issues related to Human Performance Engineering (HPE) of computing systems. *Prerequisite:* CSCI 537.

CSCI 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.

CSCI 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.

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

CSCI 544 Natural Language Processing (3, Sp) Examination of the issues which enable computers to employ and understand natural language; knowledge representation, memory modeling, parsing, language analysis, story understanding, and generation. *Recommended preparation:* CSCI 562.

CSCI 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.

CSCI 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.

CSCI 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.

CSCI 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.

CSCI 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.

CSCI 551 Computer Communications (3, FaSp) Protocol design for computer communication networks, network routing, transport protocols, internetworking. *Prerequisite:* CSCI 402, EE 450 and C-language programming.

CSCI 552 Asynchronous VLSI Design (3) (Enroll in EE 552)

CSCI 553 Computational Solution of Optimization Problems (3) (Enroll in EE 553)

CSCI 554 Real Time Computer Systems (3) (Enroll in EE 554)

CSCI 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.

CSCI 556 Introduction to Cryptography (3, Sp) 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.

CSCI 557 Computer Systems Architecture (3) (Enroll in EE 557)

CSCI 558L Internetworking and Distributed Systems Laboratory (3, FaSp) 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.

CSCI 559 Mathematical Pattern Recognition (3-3) (Enroll in EE 559)

CSCI 560L Advanced Microcomputer-Based Design (3) (Enroll in EE 560L)

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

CSCI 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.

CSCI 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.

CSCI 565 Compiler Design (4, Sp) Formal grammar; parsing methods and lexical analysis; code generation; local and global code optimization; and dynamic allocation. *Prerequisite:* CSCI 455x.

CSCI 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.

CSCI 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.

CSCI 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.

CSCI 571 Web Technologies (3, FaSp) 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.

CSCI 572 Information Retrieval and Web Search Engines (3, Sp) Examines key aspects of information retrieval as they apply to search engines; web crawling, indexing, querying and quality of results are studied. *Prerequisite:* CSCI 351, CSCI 485.

CSCI 573 Advanced Artificial Intelligence (3, FaSp) 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 561b.)

CSCI 574 Computer Vision (3, Fa) Description and recognition of objects, shape analysis, edge and region segmentation, texture, knowledge based systems, image understanding. *Prerequisite:* CSCI 455x.

CSCI 575 Wireless and Mobile Networks Design and Library (3) (Enroll in EE 579)

CSCI 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++.

CSCI 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 577a.

CSCI 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.

CSCI 579ab Computational Molecular Biology (3-3, FaSp) (Enroll in MATH 578ab)

CSCI 580 3-D Graphics and Rendering (3) The process of creating images from 3-D models. Includes transformations, shading, lighting, rasterization, texturing, and other topics.

CSCI 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.

CSCI 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.

CSCI 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.

CSCI 584 Control and Learning in Mobile Robots and Multi-Robot Systems (3, Fa) 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.

CSCI 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. Open only to computer science graduate students.

CSCI 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.

CSCI 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.

CSCI 589 Software Engineering for Embedded Systems (3) 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 577a.

CSCI 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.

CSCI 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 577ab.) *Recommended preparation:* experience in software development.

CSCI 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.

CSCI 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.

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

CSCI 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.

CSCI 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 455x; CSCI 102L; MATH 458.

CSCI 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.

CSCI 598 Mathematical Foundations for Computer-Aided Design of VLSI Circuits (3, Sp) (Enroll in EE 581)

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

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

CSCI 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.

CSCI 658 Diagnosis and Design of Reliable Digital Systems (3) (Enroll in EE 658)

CSCI 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.

CSCI 670 Advanced Analysis of Algorithms (3, FaSp) Fundamental techniques for design and analysis of algorithms. Topics include: dynamic programming; network flows; theory of NP-completeness; linear programming; approximation, randomized, and online algorithms; basic cryptography. *Prerequisite:* CSCI 570; *recommended preparation:* familiarity with algorithms and discrete mathematics.

CSCI 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.

CSCI 675 Topics in Engineering Approaches to Music Cognition (3, max 6) (Enroll in ISE 575)

CSCI 685 Advanced Topics in Database Systems (3, Sp) Advanced techniques in database management. Topics include optimization, cache management, data mining and knowledge discovery, decision support, spatial indexes, parallel and distributed systems, extendible storage. *Prerequisite:* CSCI 485 or CSCI 585.

CSCI 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 or CSCI 555.

CSCI 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.

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

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Faculty

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Presidential Chair: Simon Ramo, Ph.D.

Fluor Early Career Chair in Engineering:
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Engineering and Materials Science*)

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William M. Keck Chair in Engineering: P. Daniel Dapkus, Ph.D.

Gordon B. Marshall Early Career Chair:
Stephen B. Cronin

Jack Munushian Early Career Chair: Chongwu Zhou, Ph.D.

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C. Raghavendra, 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.; John B. Slaughter, Ph.D. (*Education*); William H. Steier, Ph.D.; Armand R. Tanguay, Jr., Ph.D. (*Biomedical Engineering, Materials Science*); Andrew J. Viterbi, Ph.D.; Alan Willner, Ph.D.*; Zhen Zhang, Ph.D.

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Adjunct Professors: Dan Goebel, Ph.D.; Mostafa Shiva, Ph.D.

Adjunct Associate Professors: Edgar Satorius, Ph.D.; Marvin Stone, Ph.D.; Ali A. Zahid, M.S.

Research Professors: Patric Muggli, Ph.D.; Gerald Pohost, M.D.

Research Associate Professors: Jeffrey Draper, Ph.D.; John Granacki, Ph.D.; Laura Marcu, Ph.D. (*Biomedical Engineering*); Joseph Touch, Ph.D. (*Computer Science*)

Research Assistant Professors: Panayiotis Georgiou, Ph.D.; Houchun Harry Hu, Ph.D.; Chunqi Jiang, Ph.D.; Sungbok Lee, Ph.D.; Quanzheng Li, Ph.D.; Bindu Madhavan, Ph.D.; Dimitrios Pantazis, Ph.D.

Professors of Engineering Practice: Edward Maby, Ph.D.; Gandhi Puvvada, M.S.; Monte Ung, Ph.D.

Senior Lecturer: Mark Redekopp, M.S.

Lecturers: Douglas Burke, Ph.D.; Shahin Nazarian, Ph.D.

Emeritus Professors: Alvin Despain, Ph.D.; Robert M. Gagliardi, Ph.D.; Hans H. Kuehl, Ph.D.*; Irving S. Reed, Ph.D. (*Mathematics, Computer Science*); Charles L. Weber, Ph.D.; Lloyd Welch, Ph.D. (*Mathematics*)

Emeritus Instructor: Sydney A. Wielin, B.S.

Joint Faculty

Joint Professors: Michael Arbib, Ph.D. (*Computer Science, Neurobiology, Biomedical Engineering*); Stanley P. Azen, Ph.D. (*Preventive Medicine and Biomedical Engineering*); Jack Feinberg, Ph.D. (*Physics*); Norberto Grzywacz, Ph.D. (*Biomedical Engineering*); Tomlinson Holman, B.S. (*Cinematic Arts*); Ellis Horowitz, Ph.D. (*Computer Science*); Vasilis Z. Marmarelis, Ph.D. (*Biomedical Engineering*); Gerard Medioni, Ph.D. (*Computer Science*); Ulrich Neumann, Ph.D. (*Computer Science*); Ramakant Nevatia, Ph.D. (*Computer Science*); Si-Zhao Qin, Ph.D. (*Chemical Engineering*); Aristides

Requicha, Ph.D. (*Computer Science*); Gaurav Sukhatme, Ph.D. (*Computer Science*); William G. Wagner, Ph.D. (*Physics*); Curt F. Wittig, Ph.D. (*Chemistry, Physics*); Stanley M. Yamashiro, Ph.D. (*Biomedical Engineering*)

Joint Associate Professors: Elaine Chew, Ph.D. (*Industrial and Systems Engineering*); Leana Golubchik, Ph.D. (*Computer Science*); Jia Grace Lu, Ph.D., (*Physics*); Ellis Meng (*Biomedical Engineering*)

Joint Adjunct Professors: Eric Fossum, Ph.D.; Kirby Holte, Ph.D.;

Joint Adjunct Associate Professors: Serge Dubovitsky, Ph.D.; Alan Kost, Ph.D.; Min-Cheol Oh, Ph.D.

Joint Research Associate Professors: Laura Marcu, Ph.D. (*Biomedical Engineering*); Keith L. Price, Ph.D. (*Computer Science*)

Joint Emeritus Professors: George A. Bekey, Ph.D. (*Computer Science, Biomedical Engineering*); Murray Gershenzon, Ph.D.* (*Materials Science*); William G. Spitzer, Ph.D. (*Physics, Materials Science*)

Joint 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 apply their technical skills in mathematics, science and engineering to the solution of complex problems encountered in modern electrical engineering practice.

Graduates will 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 compete effectively in a world of rapid technological change and assume leadership roles within industrial, entrepreneurial, academic or governmental environments in the broad context of electrical engineering.

Some graduates who choose to redirect their careers will be employed in diverse fields such as healthcare, business, law, computer science, multimedia and music through graduate-level studies and the process of lifelong learning.

Citizenship in the Global Community

Graduates will use their communication skills to function effectively both as individuals and as members of multidisciplinary and multicultural teams in a diverse global economy.

Graduates will engage in highly ethical and professional practices that account for the global, environmental and societal impact of engineering decisions.

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 563.

COMPOSITION/Writing REQUIREMENTS		UNITS	MAJOR ELECTIVES		UNITS
WRIT 140*	Writing and Critical Reasoning	4	Electives	See requirements for graduation	37
WRIT 340	Advanced Writing	3	Total units:		131
GENERAL EDUCATION (SEE PAGE 61)		UNITS			
General education* +		20	*GE Category VI is taken concurrently with WRIT 140.		
PRE-MAJOR REQUIREMENTS		UNITS	**Satisfies GE Category III requirement.		
<i>Math Requirement</i>					
MATH 125	Calculus I	4	+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.		
MATH 126	Calculus II	4			
MATH 226	Calculus III	4			
MATH 245	Mathematics of Physics and Engineering I	4	<i>Requirements for Graduation:</i>		
MATH 445	Mathematics of Physics and Engineering II	4	<i>Engineering Electives</i>		
Engineering electives are to be chosen from the courses listed under entry-level electives and areas of specialization. At least one elective must be an asterisked course.					
<i>Physics Requirement</i>					
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4	<i>Entry-Level Electives</i>		
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4	The entry-level courses listed under two of the four following topical areas are required:		
PHYS 153L	Fundamentals of Physics III: Optics and Modern Physics	4	Communication, Control and Signal Processing: EE 241 (3), EE 301 (3)		
Computer Engineering: EE 201L (4), EE 357 (3)					
Electromagnetics and Solid State: EE 337L (3), EE 338 (3)					
Electronic Devices and Circuits: EE 338 (3), EE 348L (4)					
<i>Chemistry Elective</i>					
CHEM 105aL	General Chemistry, or		<i>Areas of Specialization</i>		
CHEM 115aL	Advanced General Chemistry, or		Courses in at least one of the 10 areas of specialization listed below are required:		
MASC 110L	Materials Science	4	<i>Communication, Control and Signal Processing</i>		
Signal Processing and Communication (take four): EE 434Lx (4/CD*), EE 467 (3), EE 469 (3), EE 475 (3), EE 483 (3), EE 484x (3/CD*)					
Controls and Robotics (take four): EE 482 (3), CSCI 445 (4), EE 454L (4), EE 459Lx (3/CD*)					
<i>Engineering</i>					
ENGR 102	Engineering Freshman Academy	2	<i>Computer Engineering</i>		
Computer Architecture and Organization: EE 454L (4), EE 457 (3), EE 459Lx (3/CD*)					
Hardware/Software (take three): CSCI 402x (3), EE 454L (4), EE 457 (3)					
Computer Networks (take three): CSCI 402x (3), EE 450 (3), EE 457 (3).					
<i>Computer Science</i>					
CSCI 355	Software Design for Engineers	3	<i>Electromagnetics and Solid State</i>		
Electromechanics and Energy Systems (take three): EE 370 (3), EE 415 (3), EE 422x (3/CD*), EE 423Lx (3/CD*), EE 443 (3), EE 470 (3)					
Lasers and Photonics: EE 471 (3) or PHYS 438a (4); (take two) EE 472 (3), EE 473L (3), EE 474 (3)					
Solid State: EE 471 (3) or PHYS 438a (4); (take two) PHYS 440 (4), EE 438L (3), EE 439 (3)					
<i>Electrical Engineering</i>					
EE 101	Introduction to Digital Logic	3			
EE 105	Introduction to Electrical Engineering	3			
EE 150L	Computational Methods	3			
EE 200L	Foundations of Electrical Engineering Systems	4			
EE 202L	Linear Circuits	4			
EE 330	Electromagnetics I	3			
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science, or				
EE 464	Probability Theory for Engineers	3			
<i>Industrial and Systems Engineering</i>					
ISE 460	Engineering Economy, or				
BUAD 301	Technical Entrepreneurship	3			

Electronic Devices and Circuits

Electronic Circuits (take three): EE 447Lx (4/CD*), EE 448L (4), EE 478Lx (4/CD*), EE 479 (3)

Integrated Circuits: EE 438L (3), EE 448Lx (4), EE 477L (4).

*CD — Capstone Design Elective

Bachelor of Science in Electrical Engineering (Computers)

The Bachelor of Science in electrical engineering (computers) is earned by successfully completing the normal requirements for the Bachelor of Science in electrical engineering with the following courses chosen as EE electives: EE 454L; CSCI 455x; EE 457; EE 478L.

Bachelor of Science in Computer Engineering and Computer Science

See the listing under Computer Engineering, page 619.

Minor in Music Recording

A minor in music recording is offered through the USC Thornton School of Music to provide undergraduate students with the background necessary to enter the field of recording engineering and to familiarize them with the design needs of modern recording equipment. The minor is recommended to electrical engineering majors with extensive musical training who would like to combine their technical and musical abilities while learning the engineering applications of physical and mathematical principles to the art of music recording. See the listing under the Thornton School of Music, page 795.

Minor in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 564.

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 and through an accumulation of no more than 45 units. 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 Viterbi School of Engineering, the Master of Science in electrical engineering is also subject to the following requirements: (1) a total of at least 27 units is required; (2) every non-EE course for graduate credit requires prior written advisor approval recorded each semester on a special request form in the student's

department file; (3) no more than three courses (maximum 12 units) may be counted at the 400 level – at least 18 advisor-approved 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 residency is not allowed.

The aerospace controls option is available as an area of emphasis for MSEE students interested in learning to apply innovative control techniques to aerospace control problems. In addition to 18 approved units of electrical engineering courses, students in this option will take at least three of the following aerospace and mechanical engineering courses: 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. No more than three courses (maximum 12 units) may be counted at the 400 level – at least 18 advisor-approved units must be taken at the 500 or 600 level. Total units required for the degree is 27.

Master of Science in Electrical Engineering (Electric Power)

The Master of Science in electrical engineering (electric power) is a program option for students seeking careers in the electric power industry. The plan of study combines traditional topics in power generation, transmission and distribution with cutting-edge topics such as the integration of renewable energy sources in the “smart grid.”

The degree is earned by successfully completing the following required courses: EE 443, EE 444, EE 521, EE 524, EE 525, EE 526 and EE 527. Students must also take at least one course from two different areas:

Area 1: Construction Management

CE 501, CE 556, CE 559

Area 2: Environmental Engineering

CE 518, ENE 505, ISE 576

Area 3: Decision and Risk Analysis

ISE 561, ISE 563, PPD 587

Area 4: Public Administration

PPD 540, PPD 542, PPD 545

All other program requirements are consistent with those for the Master of Science in Electrical Engineering.

Master of Science in Electrical Engineering (Multimedia and Creative Technologies)

See listing under Multimedia and Creative Technologies, page 660.

Master of Science in Systems Architecting and Engineering

See the listing under Systems Architecting and Engineering, page 663.

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. No more than three courses (maximum 12 units) may be counted at the 400 level – at least 18 advisor-approved units must be taken at the 500 or 600 level.

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 and EE 630.

Area 3: CSCI 455x, CSCI 570, EE 557, EE 560, EE 577b (see above), EE 659 and 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 include the following: EE 501, EE 502, EE 504L, EE 506, EE 540, EE 554, EE 560, EE 590, EE 601 and EE 677.

Financial Engineering Electrical Engineering Building 100

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Master of Science in Financial Engineering

The objective of this program is the training of graduate students with engineering, applied mathematics or physics backgrounds in the application of mathematical and engineering tools to finance. Financial engineering is a multidisciplinary education program that involves the Viterbi School of Engineering, the Marshall School of Business and the College of Letters, Arts and Sciences (Department of Economics). Financial engineering uses tools from finance and economics, engineering, applied mathematics and statistics to address problems such as derivative securities valuation, strategic planning and dynamic investment strategies, and risk management, which are of interest to investment and commercial banks, trading companies, hedge funds, insurance companies, corporate risk managers and regulatory agencies.

A minimum grade point average of 3.0 must be earned on all course work applied toward the master's degree in financial engineering. 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 Viterbi School of Engineering, the Master of Science in financial engineering is also subject to the following requirements: (1) a total of at least 27 units is required, 18 of which have to be from the Viterbi School of Engineering; (2) every plan of study requires prior written approval by the contact faculty of the program; (3) 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.

Curriculum

Students are expected to have a background in probability at the level of USC's EE 464 or ISE 220 and linear algebra at the level of USC's EE 441 or MATH 225. Admitted students who do not meet prerequisites by placement examination will be assigned courses to complete the deficiencies.

The degree requirements are minimum of 27 units (18 units have to be from the School of Engineering) which corresponds to nine, three-unit courses. Three of the courses are required and the other six are electives from a restricted list of courses:

REQUIRED		UNITS
GSBA 548	Corporate Finance	3
ISE 563	Financial Engineering	3
EE 556	Stochastic Systems and Finance	3

ELECTIVES (ADVISOR APPROVED) UNITS

Finance, Business, Economics Area:

Two courses (6 units) from the following:

ECON 500	Microeconomic Analysis and Policy	4
ECON 501	Macroeconomic Analysis and Policy	4
ECON 613	Econometric and Financial Time Series I	4
FBE 529	Financial Analysis and Valuation	3
FBE 535	Applied Finance in Fixed Income Securities	3
FBE 543	Forecasting and Risk Analysis	3
FBE 554	Trading and Exchanges	3
FBE 555	Investment Analysis and Portfolio Management	3
FBE 559	Management of Financial Risk	3
FBE 589	Mortgages and Mortgage-Backed Securities and Markets	3

Optimization, Simulations, Stochastic Systems:

Three courses (9 units) from the following:

CE 645	Uncertainty Modeling and Stochastic Optimization	3
EE 517	Statistics for Engineers	3
EE 553*	Computational Solution of Optimization Problems	3
EE 562a	Random Processes in Engineering	3
ISE 520*	Optimization: Theory and Algorithms	3
ISE 536	Linear Programming and Extensions	3
ISE 538	Elements of Stochastic Processes	3
ISE 539	Stochastic Elements of Simulation	3

*Students cannot receive credit for both ISE 520 and EE 553

Systems and Control Area:

One course (3 units) from the following:

AME 541	Linear Control Systems II	3
EE 500	Neural and Fuzzy Systems	3
EE 585	Linear System Theory	3
EE 587	Nonlinear and Adaptive Control	3
EE 588	Linear Quadratic Control	3

*Students cannot receive credit for both EE 585 and AME 541

Viterbi Integrated Master of Science Program (VIP) for the General Master of Science in Electrical Engineering

The Viterbi Integrated Master of Science Program (VIP) allows selected undergraduates from U.S. institutions that are partnered with the Viterbi School to complete the Master of Science in Electrical Engineering with a 6-unit reduction of the total 27 units required.

The VIP Master of Science in Electrical Engineering is subject to the following requirements: (1) students must complete a total of at least 21 units; (2) at least 18 units must be completed at the 500 or 600 level; (3) at least 18 units must be taken in electrical engineering; (4) a minimum grade point average of 3.0 must be earned on all course work applied toward the master's degree in electrical engineering and all course work attempted at USC beyond the bachelor's degree. Students are encouraged to complete two technical courses outside their area of specialization but within EE to achieve a degree of breadth in their plan of study.

To be eligible for the VIP program, students must have completed the equivalent of at least two 400-level preparatory courses at their undergraduate institution from the list below prior to enrollment at USC. A designated department advisor for the USC VIP program must approve the course selections.

PREPARATORY COURSES UNITS

Complete equivalent of at least two courses

EE 401	Transform Theory for Engineers	3
EE 441	Applied Linear Algebra for Engineering	3
EE 448L	Communication Electronics	4
EE 450	Introduction to Computer Networks	3
EE 454L	Introduction to System Design Using Microprocessors	4
EE 457	Computer Systems Organization	3
EE 464	Probability Theory for Engineers	3
EE 465	Probabilistic Methods in Computer Systems Modeling	3

EE 470	Electromagnetics II	3
EE 477L	MOS VLSI Circuit Design	4
EE 482	Linear Control Systems	3
EE 483	Introduction to Digital Signal Processing	3
CSCI 402x	Operating Systems	3

Students applying to the VIP must be recommended by a faculty representative at a partner undergraduate institution; complete the regular graduate admission application (with exception of the GRE); and hold junior standing in electrical engineering with a 3.5 GPA or better on major related course work.

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 521, EE 524, EE 525; 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 537, EE 601, EE 604, EE 606, EE 607; Integrated Circuits-EE 471, EE 501, EE 504L, EE 506, EE 536ab, 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 669; Systems and Controls-EE 553, EE 563, EE 585, EE 586, EE 587, EE 588, EE 593.

Graduate Certificate in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 571.

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*.

EE 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.

EE 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.

EE 106L Introduction to Computer Engineering/Computer Science (2, 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. Open only to B.S., Computer Engineering and Computer Science and B.S., Computer Science majors.

EE 150L Engineering Computational Methods (3, Fa) Algorithms and computational methods for efficient solution of engineering problems. Introduction to engineering software tools.

EE 200L Foundations of Electrical Engineering Systems (4, FaSp) Mathematical models used for electronic system design. Automata, state models, differential equations, convolution, sampling, and frequency response. Communications, signal processing, and control applications. *Corequisite:* MATH 245.

EE 201L Introduction to Digital Circuits (4, FaSp) Digital system design and implementation; synchronous design of datapath and control; schematic/Verilog-based design, simulation, and implementation in Field Programmable Gate Arrays; timing analysis; simple CPU design. *Prerequisite:* EE 101.

EE 202L Linear Circuits (4, FaSpSm) 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 152L; *corequisite:* EE 200L.

EE 222 Fundamentals of Audio Engineering (3, Fa) Introduction to basic audio engineering principles and techniques, with emphasis on practical sound-system analysis and design. Sound measurements, microphones, amplifiers, loudspeakers, and system integration.

EE 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.

EE 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 202L; *corequisite:* MATH 445.

EE 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.

EE 322 Introduction to Digital Audio (3, Fa) Fundamentals of sound, acoustics and digital audio signal processing.

EE 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 152L, MATH 126.

EE 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 152L.

EE 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 202L, MATH 445, PHYS 152L.

EE 337L Engineering Nano-Systems (3, Sp) Methods to control and exploit the phenomena of nano-science, and the integration of nano-technology into systems. Development of fundamental concepts through a series of experimental modules. (Duplicates credit in former EE 238L.) *Prerequisite:* PHYS 152L.

EE 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 202L, PHYS 152L.

EE 348L Electronic Circuits (4, FaSp) Basic analog and digital circuit design using Bipolar Junction Transistors, Field Effect Transistors and integrated circuits. *Corequisite:* EE 338.

EE 351 Programming and Multimedia on the World Wide Web (3, Sp) (Enroll in CSCI 351)

EE 352L Computer Organization and Architecture (3, Sp) Computer organization and architecture. Concepts include: computer evolution and performance, system busses, cache memory, internal and external memory, input/output, operating system support, computer arithmetic. *Prerequisite:* CSCI 102.

EE 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 201L, and a high level programming language.

EE 364 Introduction to Probability and Statistics for Electrical Engineering and Computer Science (3, FaSp) Introduction to concepts of randomness and uncertainty: probability, random variables, statistics. Applications to digital communications, signal processing, automatic control, computer engineering and computer science. *Prerequisite:* MATH 225 or MATH 245 or EE 241.

EE 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.

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

EE 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.

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

EE 422x Electromagnetic Systems Design (3, FaSp) Applied electromagnetics for large- and small-scale electromechanical systems. Comprehensive design project. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 330.

EE 423Lx Loudspeaker and Sound-System Design (3, Sp) Project-based design of loudspeaker transducers, filters, and enclosures. Measurement of transfer functions, acoustical performance, distortion, Thiele-Small parameters, and power handling. Listening evaluations. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 301 or AME 302; PHYS 152L; *recommended preparation:* EE 330.

EE 434Lx 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. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 483; *recommended preparation:* EE 469.

EE 436 Introduction to Condensed Matter Physics (4, Irregular, Sp) (Enroll in PHYS 440)

EE 438L Processing for Microelectronics (3) Applications and electrical evaluation of selected processes used in electronic micro-fabrication. (Duplicates credit in former MASC 438L.) *Prerequisite:* EE 338.

EE 439 Principles of Semiconductor Processing (3) (Enroll in MASC 439)

EE 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.

EE 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.

EE 444 Power Systems Technology (3, Fa) Comprehensive assessment of the technical, environmental, and regulatory challenges that affect the future delivery and utilization of electric power. Case-study analysis. *Prerequisite:* EE 202L.

EE 445 Introduction to Robotics (4) (Enroll in CSCI 445)

EE 447Lx 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. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 348L.

EE 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 348L.

EE 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.

EE 452L Game Hardware Architectures (3, Fa) Architectural principles underlying modern game console hardware design; introduction to the programming techniques, optimization strategies, and hardware insights to create powerful games. *Prerequisite:* EE 352L.

EE 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 201L and EE 357; *recommended preparation:* EE 457.

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

EE 457 Computer Systems Organization (3, FaSp5m) Register transfer level machine organization; MIPS instruction set architecture; performance; computer arithmetic; organization and detailed implementation of non-pipelined and pipelined processors; cache and virtual memory. *Prerequisite:* EE 357.

EE 459Lx 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. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 454L.

EE 460 Introduction to Artificial Intelligence (3) (Enroll in CSCI 460)

EE 464 Probability Theory for Engineers (3, FaSp5m) Axiomatic foundations of probability, random variables, functions of several random variables, introduction to statistics, sequences of random variables. *Prerequisite:* EE 301 and MATH 445.

EE 465 Probabilistic Methods in Computer Systems Modeling (3, FaSp) Review of probability; random variables; stochastic processes; Markov chains; and simple queuing theory. Applications to program and algorithm analysis; computer systems performance and reliability modeling. *Prerequisite:* MATH 407 or EE 364.

EE 467 Introduction to Communication Systems (3) Analog and digital communication systems. (De)modulation and (de)multiplexing of AM/FM/PM, noise, digital data formats, error rates, and spectral analysis. Review of wireless, networking, and optical systems. *Prerequisite:* EE 301.

EE 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; EE 364 or MATH 407.

EE 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.

EE 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.

EE 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.

EE 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.

EE 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.

EE 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

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

EE 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 328Lx or EE 338.

EE 478Lx Digital Electronic Circuit Design (4, Sp) Design of digital electronic circuits. Laboratory experiments and an extensive term project using digital hardware. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 348L.

EE 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 348L.

EE 480 Introduction to Nanoscience and Nanotechnology (3, Fa) Next-generation nanoscale materials and electronic devices: nanoscale fabrication and characterization, nanomaterials, nanoelectronics, and nanobio-technology. *Prerequisite:* EE 338.

EE 481L Control Systems Laboratory (3, Sp) (Enroll in AME 443L)

EE 482 Linear Control Systems (3, FaSp5m) 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.

EE 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.

EE 484x 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. Capstone design experience. Open only to seniors. Not available for graduate credit. *Prerequisite:* EE 364, EE 475; *recommended preparation:* EE 467.

EE 490x Directed Research (2-8, max 8) Individual research and readings. Not available for graduate credit.

EE 499 Special Topics (2-4, max 8) Course content will be selected each semester from current developments in the field of electrical engineering.

EE 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.

EE 501 Solid State (3) (Enroll in MASC 501)

EE 502 Advanced Solid State (3) (Enroll in MASC 502)

EE 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.

EE 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.

EE 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.

EE 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.

EE 513 Solid State Energy Devices (3) Design and operation of solar photovoltaic energy converters, thermovoltaic energy converters, thermoelectric energy converters, and solid state light emitters; their roles in renewal and conservation of energy. *Recommended preparation:* EE 338.

EE 515 High Voltage Technology (3) High voltage engineering basic concepts; theoretical, design, and practical aspects of over-voltages, travelling-waves, insulation, and aging; breakdown mechanisms; insulation coordination.

EE 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.

EE 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.

EE 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.

EE 520 Introduction to Quantum Information Processing (3, Sp) Introduces the basics of quantum computation and quantum information theory: quantum bits and registers, unitary gates, algorithms, error correction, and quantum cryptography. *Recommended preparation:* EE 441, EE 464.

EE 521 Power Systems (3) Transmission lines; transients in power systems; control; stability. Special topics.

EE 522 Immersive Audio Signal Processing (3, Sp) Fundamentals of digital audio signal processing, room acoustics, and psychoacoustics. Algorithms for real-time implementation of immersive audio systems for integrated media applications. *Prerequisite:* EE 301; *recommended preparation:* EE 483.

EE 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.

EE 525 Power System Protection (3) Theory of system and equipment protection, characteristics of relays, relay coordination, and system considerations. *Prerequisite:* EE 510.

EE 526 Renewable Energy in Power Systems (3) Renewable energy sources and their integration in electrical networks. Power-flow control from highly variable resources. Cost analysis and planning. *Prerequisite:* EE 444; *corequisite:* EE 521.

EE 527 Net-Centric Power-System Control (3) Control and stability of large-scale systems such as the electric power grid. Integration with information networks. *Corequisite:* EE 521; *recommended preparation:* EE 484 or equivalent.

EE 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.

EE 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.

EE 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.

EE 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 457.

EE 534 Materials Characterization (3) (Enroll in MASC 534)

EE 535 Mobile Communications (3, Fa) The mobile communication channel; techniques used to combat the channel; cellular communications; multiple-access techniques; example mobile communication systems. *Prerequisite:* EE 562a; *recommended preparation:* EE 567.

EE 536ab Mixed-Signal Integrated Circuit Design (3-3, FaSp) a: MOSFET operation and models; voltage references and biasing; elementary amplifier configurations; design techniques for high-speed operational amplifiers, comparators and transconductors; compensation methods. *b:* Non-linear integrated circuits, data-converter architectures and implementations, comprehensive design project. (Duplicates credit in former EE 533ab.) *Prerequisite:* EE 479.

EE 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. *Prerequisite:* EE 338.

EE 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 micro-cellular (PCS), including the industry standard IS-95. *Prerequisite:* EE 564; *recommended preparation:* EE 568.

EE 539 Engineering Quantum Mechanics (3, Fa) Quantum mechanics for engineering majors who work with solid-state devices, quantum electronics, and photonics. Schrodinger equation, perturbation theory, electronic and optical processes.

EE 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.

EE 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.

EE 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.

EE 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. (Lab is required for the *b* section only.) (Duplicates credit in former EE 485abL.) *Prerequisite:* EE 543a.

EE 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 348L, EE 364.

EE 545 Robotics (3, FaSp) (Enroll in CSCI 545)

EE 546 Intelligent Embedded Systems (3, Sp) (Enroll in CSCI 546)

EE 547 Sensing and Planning in Robotics (3, Fa) (Enroll in CSCI 547)

EE 548 Analytical Methods in Robotics (3) (Enroll in AME 548)

EE 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.

EE 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.

EE 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, EE 562a.

EE 552 Asynchronous VLSI Design (3, FaSp)

Asynchronous channels and architectures; implementation design styles; controller synthesis; hazards, and races; Petri-nets; performance analysis, and optimization; globally asynchronous locally synchronous design. Open only to graduate students. *Prerequisite:* EE 477.

EE 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.

EE 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.

EE 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.

EE 556 Stochastic Systems and Finance (3)

Introductory probability; Markov chains; Martingales and stopping times; Brownian motion; Ito's calculus and formula; Black-Scholes formula; arbitrage pricing and risk neutral measures; options.

EE 557 Computer Systems Architecture (3, FaSp)

Computer architecture from a design perspective: Pipelined processors, speculative execution, VLIW, vector processors, memory systems, interconnection networks, shared-memory and message-passing multiprocessors, chip multiprocessors. *Prerequisite:* EE 457.

EE 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.

EE 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.

EE 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, EE 454L; *recommended preparation:* familiarity with CAD tools.

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

EE 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 562a.

EE 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 562a.

EE 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 562a.

EE 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 565a before *b*.

EE 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.

EE 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. *Corequisite:* EE 464 or EE 465; *recommended preparation:* EE 441.

EE 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.

EE 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.

EE 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.

EE 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 571a.

EE 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.

EE 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.

EE 574 Computer Vision (3, Fa) (Enroll in CSCI 574)

EE 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 570ab.

EE 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.

EE 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.

EE 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.

EE 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 562a.

EE 581 Mathematical Foundations for Computer-Aided Design of VLSI Circuits (3, Sp) Mathematical techniques employed in computer-aided-design systems, including: graph theory, algorithmic and heuristic techniques for combinatorial problems, data structures and modeling. *Corequisites:* EE 457, EE 477.

EE 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 562a.

EE 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 562a.

EE 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.

EE 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.

EE 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.

EE 588 Linear Quadratic Control (3, Sp)

Linear systems with quadratic cost, Riccati equations, observers, Kalman-Bucy filters, separation principle, discrete linear optimal control systems. *Prerequisite:* EE 585; *recommended preparation:* EE 482, EE 562a.

EE 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.

EE 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.

EE 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.

EE 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.

EE 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.

EE 594abz Master's Thesis (2-2-0, FaSpSm)

For the master's degree. Credit on acceptance of thesis. Graded IP/CR/NC.

EE 595 Algebraic Coding Theory (3, Fa)

Finite field theory; Reed Solomon codes; algebraic codes; algebraic decoding methods; examples. *Prerequisite:* EE 441, EE 464.

EE 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 441, EE 483; *recommended preparation:* EE 569, MATH 570a.

EE 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.

EE 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.

EE 606 Nonequilibrium Processes in Semiconductors (3) Non-equilibrium processes in modern semiconductor devices. Carriers lifetime and trapping; luminescence; hot carrier and high field effects.

EE 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.

EE 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.

EE 612 Science and Practice of Nanotechnology (3, Fa) In-depth discussions of important topics in nanotechnology, including both the implementation and the underlying theory. *Prerequisite:* EE 330 or EE 470.

EE 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.

EE 632 Integrated Communication Systems (3) Analysis and design of high-speed integrated communication systems at circuit and system levels. Emphasis on broadband wireless applications. Transceiver architectures, amplifiers, oscillators, frequency synthesizers. *Prerequisite:* EE 536a.

EE 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.

EE 645 Uncertainty Modeling and Stochastic Optimization (3) (Enroll in CE 645)

EE 649 Stochastic Network Optimization (3, Sp) Optimization of wireless and ad-hoc mobile networks; opportunistic scheduling, flow control; backpressure routing; queue stability; energy-delay and utility-delay tradeoffs. *Prerequisite:* EE 465 or EE 562a; *recommended preparation:* EE 549 or EE 550.

EE 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.

EE 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.

EE 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.

EE 657 Parallel and Distributed Computing (3, FaSpSm) Parallel programming models/software tools, multiprocessor systems, multi-computer clusters, latency tolerance, multithreading, fast message passing/middleware, interconnection networks, SMP, cluster, and grid computing applications. *Prerequisite:* EE 557.

EE 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.

EE 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.

EE 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 562a; *recommended preparation:* EE 567, EE 564 and a Bachelor of Science degree in Electrical Engineering.

EE 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.

EE 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.

EE 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 562a.

EE 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.

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

EE 675 Topics in Engineering Approaches to Music Cognition (3, max 6) (Enroll in ISE 575)

EE 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.

EE 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. *Prerequisite:* EE 581; *recommended preparation:* EE 577a.

EE 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.

EE 690 Directed Research (1-4, maximum number to be determined by the department, FaSpSm) Laboratory study of specific problems by candidates for the degree Engineer in Electrical Engineering. Graded CR/NC.

EE 691 Advanced Magnetic Resonance Imaging (3, Fa) Advanced clinical and research applications, sparse sampling, RF pulse design, analysis of free precession sequences, NMR relaxation, in-vivo spectroscopy and other advanced topics. *Prerequisite:* EE 441, EE 562a, EE 591.

EE 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.

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

Green Technologies

Master of Science in Green Technologies

Green technologies are concerned with intelligent engineering solutions to the increased global energy demand, improved energy efficiency in commercial and consumer products, minimized footprint of energy usage, and smartly engineered industrial ecology for sustainability. The Master of Science in Green Technologies is an interdisciplinary program that is related to almost all traditional engineering disciplines which include fossil energy, alternative energy, energy conversion, energy distribution, energy conservation, environmental engineering, and information and material science approaches to these engineering aspects. It addresses both the supply side in terms of alternative energy sources as well as the demand side in terms of energy efficiency and carbon waste management.

The program requires 27 units, or about 9 courses; 18 units must be at the 500 level and above. At least 18 units must be taken in the Viterbi School of Engineering. All courses must be approved in advance by the appropriate departmental advisors. Students with B.S. degrees in engineering and science disciplines can be accepted to the program.

REQUIRED COURSES (MINIMUM THREE COURSES) UNITS

These are courses in the major topical areas of the theme		
AME 577	Survey of Energy and Power for a Sustainable Future	3
AME 578	Modern Alternative Energy Conversion Devices	3
CHE 510	Energy and Process Efficiency	3
EE 513	Solid State Energy Devices	3
ISE 576	Industrial Ecology: Technology-Environment Interaction	3

TECHNICAL ELECTIVES (MINIMUM THREE COURSES) UNITS

AME 581	Introduction to Nuclear Engineering	3
CE 518	Carbon Capture and Sequestration	3
CE 587	Transportation Energy Analysis	3
EE 516	Electric Power Distribution	3
EE 521	Power Systems	3
ENE 505	Energy and the Environment	3
GEOG 601	Sustainable Cities	4
POSC 546	Seminar in Environmental Policy	4

Other technical electives can be taken with approval of faculty advisors in the participating departments to achieve depth in subject areas relevant to the student's undergraduate major. For example, students with previous electrical engineering backgrounds will likely take courses in nanotechnology, smart-grid technologies and efficient power distribution. Those with mechanical engineering backgrounds may take courses in combustion, advanced design and radiation heat transfer. Those with backgrounds in chemical engineering may take courses in process design, materials efficiency and nanotechnology.

Special approval may be granted to waive prerequisites if students have taken the equivalent course work elsewhere.

Daniel J. Epstein Department of Industrial and Systems Engineering

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

Associate Chair and Program Co-Director,
Systems Architecting and Engineering: F. Stan
Settles, Ph.D.

Program Director, Systems Architecting and
Engineering: Azad Madni, Ph.D.

Associate Director, Systems Architecting and
Engineering: George Friedman, Ph.D.

Faculty

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

Epstein Family Chair: Dorit S. Hochbaum,
Ph.D.

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

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

Fluor Professor in Process Engineering: S. Joe
Qin, Ph.D. (*Chemical Engineering and Materials
Science, Electrical Engineering/Systems*)

TRW Professor of Software Engineering: Barry
Boehm, Ph.D. (*Computer Science*)

Professors: Maged Dessouky, Ph.D.*; Randolph
Hall, Ph.D.; Carl F. Kesselman, Ph.D.
(*Computer Science*); Behrokh Khoshnevis,
Ph.D. (*Civil and Environmental Engineering*;

Aerospace and Mechanical Engineering); Azad
Madni, Ph.D.; Najmedin Meshkati, Ph.D.
(*Civil and Environmental Engineering*)*; James
E. Moore II, Ph.D. (*Civil and Environmental
Engineering; Policy, Planning, and Development*);
Milind Tambe, Ph.D. (*Computer Science*);
Detlof von Winterfeldt (*Policy, Planning, and
Development*)

Associate Professors: Elaine Chew, Ph.D.
(*Electrical Engineering/Systems, Music*);
Fernando Ordoñez, Ph.D. (*Computer Science*);
Mansour Rahimi, Ph.D.

Assistant Professors: Yong Chen, Ph.D.; Qiang
Huang, Ph.D.; Rahul Jain, Ph.D. (*Electrical
Engineering/Systems*); Shinyi Wu, Ph.D.; Maria
Yang, Ph.D.

Visiting Assistant Professor: Stephen Stoyan,
Ph.D.

Adjunct Professors: Paul J. Kern; Michael
Mann, Ph.D.

Adjunct Associate Professors: Daniel Harvey,
Ph.D.; James Hines; Thomas McKendree,
Ph.D.; Tasos Soukias, Ph.D.; Marilee
Wheaton

Research Professors: Yigal Arens, Ph.D.; Wanda
M. Austin, Ph.D.; Malcolm Currie, Ph.D.;
Mohamed I. Dessouky, Ph.D.; Stephen
C. Hora, Ph.D. (*Policy, Planning, and
Development*)

Research Assistant Professors: Jo Ann Lane,
Ph.D.; Richard Waltz, Ph.D.

Professor of the Practice of Industrial and Systems
Engineering: George Friedman, Ph.D.

Associate Professor of the Practice of Industrial
and Systems Engineering: Kurt Palmer, Ph.D.*

Senior Lecturers: Geza Bottlik, Engineer,
P.E.; Nitin Kale, M.S. (*Information Technology
Program*); Dana Sherman, Esq. (*Civil and
Environmental Engineering*); Richard Vawter,
M.S. (*Information Technology Program*)

Emeritus Professors: Clinton J. Ancker, Jr.,
Ph.D., P.E.; Gerald A. Fleischer, Ph.D., P.E.;
Homer H. Grant, M.S.; Ralph Keeney, Ph.D.
(*Information and Operations Management*);
Gerald Nadler, Ph.D., P.E.; Peter Will, Ph.D.

*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-fifth of their
class; seniors in the upper one-third of their
class; master's degree students who have
completed at least one-third of the courses
required for their degree and rank among
the top 10 students in all ISE master's
degree programs; and doctoral students rec-
ommended by the department chair. The
advisor is Kurt Palmer, Associate Professor
of the Practice of Industrial and Systems
Engineering, (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.

Undergraduate Degree Requirements

Undergraduate Education Program Mission

The mission of the Daniel J. Epstein
Department of Industrial and Systems
Engineering undergraduate programs is to:

(1) Provide students: the skills and knowl-
edge to obtain employment and achieve lead-
ership with the industrial and systems

engineering profession or to proceed with
graduate education; the intellectual resources
to continue life-long learning; and the knowl-
edge of professional ethics and critical reason-
ing skills necessary for contributing to society.

(2) Provide employers of industrial and
systems engineering professionals with
candidates who are technically competent,

business aware, collaborative, able to commu-
nicate effectively, and ethically grounded.

(3) Maintain and enhance the reputation of
the Epstein department within the engineer-
ing, business and academic communities.

Undergraduate Education Program Objectives

Graduates of the Bachelor of Science in Industrial and Systems Engineering programs are prepared to achieve any of the following accomplishments:

- (1) Obtain employment in an organization that values people who demonstrate both technical competence and business awareness.
- (2) Pursue graduate or professional education.
- (3) Assume a leadership role in their employment organization or community.
- (4) Utilize critical reasoning, collaboration and creativity to contribute to society.

Undergraduate Education Program Outcomes

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 program prepares 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) Synthesize inventive and innovative solutions for creation and improvement of products, processes and systems.
- (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 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 563.

COMPOSITION/WRITING REQUIREMENT UNITS

WRIT 140*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3

GENERAL EDUCATION (SEE PAGE 61) UNITS

General education* +	20
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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 Requirement

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
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MAJOR REQUIREMENTS UNITS

Business

ACCT 410x	Accounting for Non-Business Majors	4
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Engineering

ENGR 102	Engineering Freshman Academy	2
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Electrical Engineering

AME 341a	Mechnoptics Laboratory I, or	3
EE 326L***	Essentials of Electrical Engineering	4

Computer Science

CSCI 101L	Fundamentals of Computer Programming	3
ISE 382	Database Systems: Concepts, Design and Implementation	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 UNITS

Approved engineering electives***	3
Free electives	7
Total units:	128

*GE Category VI is taken concurrently with WRIT 140.

**GE Category III is fulfilled by PHYS/CHEM requirement.

***Students selecting EE 326 are only required to complete 2 units of approved engineering elective.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

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 563.

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 (SEE PAGE 61) UNITS

General education* +		20
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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 Requirement

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

ENGR 102	Engineering Freshman Academy	2
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COMPUTER SCIENCE TRACK UNITS

Computer Science

CSCI 101L	Fundamentals of Computer Programming	3
CSCI 102L	Data Structures	3
CSCI 200L	Object-Oriented Programming	3
CSCI 201L	Principles of Software Development	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 310L	Production I: Facilities and Logistics	4
ISE 330	Introduction to Operations Research: Deterministic Models	3

ISE 382	Database Systems: Concepts, Design and Implementation	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 elective	3
Information technology program/ information and operations management electives	6
Approved engineering elective	3
Free electives	9

INFORMATION AND

OPERATIONS MANAGEMENT TRACK UNITS

Business

IOM 431	Managing the Digital Revolution for Your Business	4
IOM 433	Business Information Systems Analysis and Design	4
IOM 435	Business Database Systems	4

Computer Science

CSCI 101L	Fundamentals of Computer Programming	3
ITP 482L	Engineering Database Applications	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 310L	Production I: Facilities and Logistics	4
ISE 330	Introduction to Operations Research: Deterministic Models	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***

Information technology program/ information and operations management electives	6
Approved engineering elective	3
Free electives	10
Total units:	128

*GE Category III is fulfilled by PHYS/CHEM requirement.

**Electives in the CSCI/ITP/IOM 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.

+The university allows engineering majors to replace the GE Category IV with a second course in Categories I, II or VI.

Computer Science Electives: CSCI 351, CSCI 377, CSCI 485, EE 450

ITP/IOM Electives: ITP 215Lx, ITP 320Lx, ITP 321x, ITP 325x, ITP 454x, ITP 457x, ITP 486, ITP 487Lx, IOM 428

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, ITP 482L.

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

Minor in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 564.

Graduate Degree Requirements

Master of Digital Supply Chain Management

This interdisciplinary program is offered jointly with the Department of Information and Operations Management in the Marshall School of Business. The program is available via distance education. See page 160 for program requirements.

Engineering Management Program Ethel Percy Andrus Gerontology Center 240 (213) 740-4893

Program Director: Geza Bottlik, Engineer, P.E.

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 Epstein Department of Industrial and Systems Engineering. A total of 18 units must be at the 500 level or above. The program is available via distance education.

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):

ACCT 509	Concepts of Financial and Management Accounting
CE 502	Construction Accounting and Finance
ISE 565	Law and Finance for Engineering Innovation
ISE 566	Financial Accounting Analysis for Engineering
PPD 516x	Financial Accounting in the Public and Nonprofit Sectors

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 576	Industrial Ecology: Technology-Environment Interaction
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
ISE 563	Financial Engineering

Enterprises (3 units):

ISE 507	Six-Sigma Quality Resources for Health Care
ISE 508	Health Care Operations Improvement
ISE 517	Modern Enterprise Systems
ISE 527	Quality Management for Engineers
ISE 564	Performance Analysis
SAE 550	Systems Architecting and the Political Process
SAE 551	Lean Operations

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 536	Linear Programming and Extensions
ISE 538	Elements of Stochastic Processes
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

Health Systems Management Engineering Program

Ethel Percy Andrus Gerontology Center 240
(213) 740-4893

Program Director: Shinyi Wu, Ph.D.

This program is jointly sponsored by the Epstein Industrial and Systems Engineering Department and the School of Policy, Planning, and Development, and administered by the Epstein Industrial and Systems Engineering Department. This degree is designed for students with sufficiently quantitative bachelor's degrees in engineering, the sciences or applied social science who are interested in operations management and health care applications, and whose career objectives lead to increasing technical management responsibilities in large health care organizations, particularly hospitals. Students with less quantitative social science or other non-technical backgrounds interested in health administration objectives may also want to consider the Master of Health Administration program in the School of Policy, Planning, and Development.

Master of Science in Health Systems Management Engineering

At least 34 units are required for the degree. Some combinations of courses may require students to complete more than 34 units. Admitted students may count courses taken for completion of the Graduate Certificate in Health Systems Operations toward this degree. This program is available via distance education.

Applicants to the program are expected to have mathematical competence representative of that provided by an undergraduate degree in engineering; competence in basic descriptive and inferential statistics; competence in microeconomics; and competence in accounting at the level of PPD 516x Financial Accounting in the Public and Nonprofit Sectors, ACCT 509 Concepts of Financial and Management Accounting, or ISE 566 Financial Accounting Analysis for Engineering. Admitted students who do not meet the course work requirements will be assigned courses to complete the deficiencies.

CORE (FOUR COURSES, 14 UNITS)		UNITS
ISE 507	Six-Sigma Quality Resources for Health Care	3
ISE 508	Health Care Operations Improvement	3
PPD 509	Problems and Issues in the Health Field	4
PPD 545	Human Behavior in Public Organizations	4

ECONOMICS AND FINANCE

(SELECT TWO COURSES, AT LEAST 6 UNITS)

		UNITS
ISE 561	Economic Analysis of Engineering Projects	3
ISE 562	Value and Decision Theory	3
ISE 563	Financial Engineering	3
PPD 510a	Financial Management of Health Services	4
PPD 514	Economic Concepts Applied to Health	4

INFORMATION SYSTEMS

(SELECT ONE COURSE, AT LEAST 2 UNITS)

		UNITS
BME 527	Integration of Medical Imaging Systems	3
BME 528	Medical Imaging Informatics	3
ISE 583	Enterprise Wide Information Systems	3
PM 538	Introduction to Biomedical Informatics	3
PPD 511	Health Information Systems	2

MANAGEMENT (SELECT TWO COURSES, AT LEAST 6 UNITS)

		UNITS
ISE 515	Engineering Project Management	3
ISE 544	Management of Engineering Teams	3
ISE 527	Quality Management for Engineers	3
ISE 564	Performance Analysis	3
PPD 513	Legal Issues in Health Care Delivery	4

QUANTITATIVE METHODS (SELECT TWO COURSES, AT LEAST 6 UNITS)

		UNITS
Select one course, at least 3 units:		
ISE 530	Introduction to Operations Research	3
PPD 557	Modeling and Operations Research	4
Select one course, at least 3 units:		
ISE 525	Design of Experiments	3
ISE 562	Value and Decision Theory	3
ISE 570	Human Factors in Engineering	3
ISE 580	Advanced Concepts in Computer Simulation	3
PM 603	Structural Equation Modeling	4
PPD 558	Multivariate Statistical Analysis	4

Students may not simultaneously satisfy the Quantitative Methods and Economics and Finance requirements with only ISE 562 Value and Decision Theory. Two courses are needed.

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 Viterbi School of Engineering. This program enhances the technical capabilities of the industrial engineer. The program is available via distance education.

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 Epstein Department of Industrial and Systems Engineering. 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

<i>Systems Design</i>		
ISE 510	Advanced Computational Design and Manufacturing	3
ISE 525	Design of Experiments	3
ISE 527	Quality Management for Engineers	3
ISE 576	Industrial Ecology: Technology-Environment Interaction	3
SAE 541	Systems Engineering Theory and Practice	3
SAE 549	Systems Architecting	3
<i>Production</i>		
ISE 511L	Computer Aided Manufacturing	3
ISE 513	Inventory Systems	3
ISE 517	Modern Enterprise Systems	3
SAE 551	Lean Operations	3
<i>Systems Performance</i>		
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
ISE 583	Enterprise Wide Information Systems	3

Quantitative Methods

ISE 532	Network Flows	3
ISE 536	Linear Programming and Extensions	3
ISE 538	Elements of Stochastic Processes	3
ISE 563	Financial Engineering	3
Advisor approved electives		9
Total units:		30

Operations Research Engineering Program
Ethel Percy Andrus
Gerontology Center 240
(213) 740-4891

Program Director: Maged Dessouky, Ph.D.

Master of Science in Operations Research Engineering

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. This program is available via distance education.

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, or	
ISE 583	Enterprise Wide Information Systems	3

Select at least two of the following 10 courses: 6 units

CE 645	Uncertainty Modeling and Stochastic Optimization (3)
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 539	Stochastic Elements of Simulation (3)
ISE 562	Value and Decision Theory (3)
ISE 563	Financial Engineering (3)
ISE 576	Industrial Ecology: Technology-Environment Interaction (3)
SAE 541	Systems Engineering Theory and Practice (3)

400- or 500-level computer science course, approved by faculty advisor	3
Two electives, approved by faculty advisor	6
	30

Master of Science in Product Development Engineering

This interdisciplinary program is offered jointly with the Department of Aerospace and Mechanical Engineering. The program is available via distance education. See the listing under Product Development Engineering, page 662.

Master of Science in Systems Architecting and Engineering

See the listing under Systems Architecting and Engineering, page 663. The program is available via distance education.

Dual Degree Program (M.S., Industrial and Systems Engineering/M.B.A.)

The USC Marshall School of Business in conjunction with the Epstein 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 including all required courses in an M.B.A. program 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 ELECTIVES (CHOOSE ONE FROM EACH GROUP)		9

Systems Design (3 units)

ISE 525	Design of Experiments
ISE 527	Quality Management for Engineers
SAE 541	Systems Engineering Theory and Practice

Information Systems (3 units)

ISE 580	Advanced Concepts in Computer Simulation
ISE 582	Web Technology for Industrial Engineering
ISE 583	Enterprise Wide Information Systems

Quantitative Methods (3 units)

ISE 532	Network Flows
ISE 536	Linear Programming and Extensions
ISE 538	Elements of Stochastic Processes

Elective	Chosen with advisor approval	3
		18

Engineer in Industrial and Systems Engineering

Requirements for the Engineer in industrial and systems engineering are the same as set forth in the general requirements.

Doctor of Philosophy in Industrial and Systems Engineering

The degree Doctor of Philosophy in industrial and systems engineering is also offered. See general requirements for graduate degrees.

Graduate Certificates

Graduate Certificate in Engineering Technology Commercialization

See listing in the Special Educational Opportunities section, page 571.

Graduate Certificate in Health Systems Operations

This 17-unit graduate certificate is jointly sponsored by the Epstein Industrial and Systems Engineering Department and the School of Policy, Planning, and Development (Master of Health Administration program), and administered by the Epstein ISE Department. This certificate is designed for students with bachelor's degrees in applied social science, engineering or the sciences, who are interested in operations management and health care applications. The courses taken for the certificate may be applied later to the Epstein ISE Department's Master of Science in Engineering Management degree, the School of Policy, Planning, and Development's Master of Health Administration degree or the jointly sponsored M.S. in Health Systems Management Engineering degree subject to approval of the appropriate academic unit. This program is available via distance education.

REQUIRED COURSES		UNITS
ISE 507	Six-Sigma Quality Resources for Health Care	3
ISE 508	Health Care Operations Improvement	3
PPD 509	Problems and Issues in the Health Field	4
PPD 513	Legal Issues in Health Care Delivery, or	
PPD 514	Economic Concepts Applied to Health	4
PPD 557	Modeling and Operations Research (4), or	
ISE 530	Introduction to Operations Research (3), or	
ISE 562	Value and Decision Theory (3)	3-4
		17-18

Graduate Certificate in Network Centric Systems

See listing under Systems Architecting and Engineering, page 665. The program is available via distance education.

Graduate Certificate in Optimization and Supply Chain Management

This abbreviated interdisciplinary program is offered jointly with the Department of Information and Operations Management in the Marshall School of Business. See page 160 for program requirements.

Graduate Certificate in Systems Architecting and Engineering

See listing under Systems Architecting and Engineering, page 665. The program is available via distance education.

Graduate Certificate in System Safety and Security Applications

Applications for this program are not currently being accepted.

Graduate Certificate in Transportation Systems

This abbreviated interdisciplinary program is offered jointly with the Astani Department of Civil and Environmental Engineering and the School of Policy, Planning, and Development. See listing under Civil Engineering, page 611.

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*.

ISE 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.

ISE 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.

ISE 225 Engineering Statistics I (3, Sp) Sampling distributions; parameter estimation, hypothesis testing; analysis of variance; regression; nonparametric statistics. *Prerequisite:* ISE 220.

ISE 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 110L or CHEM 105aL or CHEM 115aL.

ISE 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.

ISE 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.

ISE 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.

ISE 344 Engineering Team Management (3) Examine team formation and team dynamics including organizational behavior, group dynamics, psychology, and business management, all in the context of engineering development; decision-making and negotiation. Open only to juniors and seniors.

ISE 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.

ISE 382 Database Systems: Concepts, Design and Implementation (3, Sp) Concepts in modeling data for industry applications. Designing and implementing robust databases. Querying databases to extract business intelligence; Global Enterprise Resource Planning with databases. *Prerequisite:* CSCI 101L.

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

ISE 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.

ISE 415 Industrial Automation (3, Irregular)

Traditional (automobile) and modern (computer based) concepts in Industrial Automation. Computer control concepts (sensors, actuators), robotics, flexible manufacturing systems. *Prerequisite:* senior level status.

ISE 422L Configuring Enterprise Resource Planning Systems (3, FaSp) (Enroll in ITP 422L)

ISE 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.

ISE 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 101L; *corequisite:* ISE 225.

ISE 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.

ISE 455Lx Enterprise Information Portals (3, Sp) (Enroll in ITP 455Lx)**ISE 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.

ISE 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.

ISE 482L Engineering Database Applications (3) (Enroll in ITP 482L)

ISE 490x Directed Research (2-8, max 8, FaSp) Individual research and readings. Not available for graduate credit.

ISE 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. *Corequisite:* ISE 225, ISE 310; ISE 382 or IOM 435. *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.

ISE 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.

ISE 502 Construction Accounting and Finance (3) (Enroll in CE 502)

ISE 507 Six-Sigma Quality Resources for Health Care (3, Fa) Comprehensive study of Six-Sigma and Lean metrics, methods, and systems with emphasis on their application to health care services.

ISE 508 Health Care Operations Improvement (3, Sp)

Improving operations, patient flow, quality and processes. Students will become familiar with methods for implementing change in health care settings such as hospitals or clinics.

ISE 510 Advanced Computational Design and Manufacturing (3)

Study advanced concepts behind computational representations, algorithms, and mathematical foundations, and their applications in computer-aided design and manufacturing. Develop hands-on computational skills in team projects. *Recommended preparation:* bachelor's degree in industrial engineering; programming experience, C++ preferred.

ISE 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.

ISE 512 Software Management and Economics (3, Fa) (Enroll in CSCI 510)

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 528 Advanced Statistical Aspects of Engineering Reliability (3)

Advanced statistical methods applied to reliability engineering. Experimental design analysis and interpretation of multifactor reliability problems.

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 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.

ISE 539 Stochastic Elements of Simulation (3, Sp) Simulation techniques combined with probabilistic analysis for solving problems in inventory theory, queuing theory, financial engineering, decision analysis, and other fields having a stochastic element. *Corequisite:* ISE 538.

ISE 543 Case Studies in Systems Engineering (3, FaSp) (Enroll in SAE 543)

ISE 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.

ISE 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.

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

ISE 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.

ISE 556 Stochastic Systems and Finance (3, Sp) (Enroll in EE 556)

ISE 560 Analysis of Algorithms (3, FaSp) (Enroll in CSCI 570)

ISE 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.

ISE 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.

ISE 563 Financial Engineering (3, Sp) Concepts underlying the economic analysis of engineering projects; applications to call and put options; utility theory and mathematical optimizations models; and simulation. *Recommended preparation:* ISE 220 or an equivalent course in probability.

ISE 564 Performance Analysis (3) 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.

ISE 565 Law and Finance for Engineering Innovation (3) Students will identify, formulate and resolve legal, financial and ethical issues affecting innovation in engineering organizations including legal structures, financing and intellectual property rights. Open only to graduate students.

ISE 566 Financial Accounting Analysis for Engineering (3, Sp) Identification, formulation, and solution of financial accounting problems in engineering enterprises. Legal context of financial decisions, process cost determination and allocation, financial reports, and reporting systems. Open only to graduate students.

ISE 567 Collaborative Engineering Principles and Practice (3, Sp) Scientific principles and industrial practices defining how a team of stakeholders should collaboratively work together to reach agreement on complex engineering tasks. Open only to graduate students in engineering.

ISE 570 Human Factors in Engineering (3, Fa) Psychological and physiological characteristics of humans; how they limit engineering design of machines and human-machine systems.

ISE 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.

ISE 573 Work Physiology (3) Survey of metabolic processes in the performance of physical work, study of individual and environmental factors affecting these processes.

ISE 575 Topics in Engineering Approaches to Music Cognition (3, max 6) Computational research in music cognition, including computational methods for music analysis, such as the abstracting and extracting of pitch and time structures. Computational research in expressive performance, the manipulation of parameters (e.g., tempo, loudness, articulation) to focus attention, facilitate parsing, and create emotional affect. Open to graduate engineering students only. *Recommended preparation:* programming experience (C++ or Java), basic signal processing and music theory.

ISE 576 Industrial Ecology: Technology-Environment Interaction (3) Concepts and methods to analyze the environmental impacts of industrial systems, including lifecycle assessment, material flow analysis, design for environment and sustainable consumption.

ISE 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 435.

ISE 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.

ISE 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.

ISE 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.

ISE 587 Risk Analysis (4) (Enroll in PPD 587)

ISE 589 Port Engineering: Planning and Operations (3, Fa) (Enroll in CE 589)

ISE 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.

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

ISE 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.

ISE 645 Uncertainty Modeling and Stochastic Optimization (3, Sp) (Enroll in CE 645)

ISE 650abc 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.

ISE 670 Advanced Analysis of Algorithms (3, Fa) (Enroll in CSCI 670)

ISE 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.

ISE 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.

ISE 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: Ashish Soni, M.S.

Instructors: Patrick Dent, M.S.; Joseph Greenfield, M.S.; Trina Gregory, B.A.; Nitin Kale, M.S.; Tom Sloper, B.A.; Richard Vawter, 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 3D animation minor is a cross-disciplinary program merging theoretical concepts and state of the art techniques to prepare students to apply 3D animation across a wide range of industry applications. The courses integrate three major disciplines – cinema, fine arts and information technology.

Students 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.

For specific information on admission and application procedures, contact the Information Technology Program at (213) 740-4542.

Requirements for completion (five core courses plus minimum 9 units of electives)
Minimum units: 22

CORE COURSES (13 UNITS)		UNITS
CTAN 330	Animation Fundamentals	2
CTAN 451	History of Animation	2
FA 101a	Drawing	4
ITP 215Lx	3D Modeling, Animation, and Special Effects	2
ITP 414x	Seminar and 3D Portfolio Development	3
ELECTIVE COURSES (9 UNITS)		UNITS
ITP 305x	Advanced 3D Modeling, Animation, and Special Effects	3
ITP 315x	3D Character Animation	3
ITP 360x	3D Compositing and Visual Effects	3
ITP 470x	Information Technology Practicum	3-4
CTAN 452	Introduction to 3-D Computer Animation	2

Minor in Applied Computer Security

The minor in applied computer security combines both theoretical concepts and technical skills to prepare students for a career in information security while incorporating their major field of work. Students will study various areas of computer security, including hacking, ethics, forensics, networking and security management. Electives are available depending on the students' academic and professional goals.

Students should meet the regular admissions standards and have a declared USC major. Students 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 (five core courses plus one elective)

Minimum units: 18

REQUIRED COURSES (14 UNITS)		UNITS
ITP 125Lx	From Hackers to CEOs: Introduction to Information Security	2
ITP 325x	Ethical Hacking and Systems Defense	3
ITP 357x	Enterprise Network Design	3
ITP 370x	Information Security Management	3
ITP 375x	Digital Forensics	3
ELECTIVES (4 UNITS)		UNITS
ITP 425x	Web Application Security	4
ITP 457	Network Security	4
ITP 475x	Advanced Digital Forensics	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

Minimum units: 24

REQUIRED COURSES (24 UNITS)	UNITS
CTIN 483 Introduction to Game Development	4
CTIN 484L* Intermediate Game Development	2
CTIN 488 Game Design Workshop	4
CTIN 489* Intermediate Game Design Workshop	2
ITP 280 Video Game Production	4
ITP 391x Designing and Producing Video Games	4
ITP 491x Level Design and Development for Video Games	4

*CTIN 483 and CTIN 488 are prerequisites; enrollment in CTIN 484L and CTIN 489 is concurrent.

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)	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 is designed to help students incorporate the Web in their major field of study by combining theoretical concepts and practical applications of Web technologies. Upon completion of the minor, students will be able to design, develop and apply major Web technologies and advancements. The broad areas of study will be publishing, programming, databases, and multimedia. An elective will be chosen depending on the students' academic and professional goals.

Students should meet the regular admissions standards and have a declared USC major.

Requirements for completion (five core courses plus one elective)

Minimum units: 18

CORE COURSES (15 UNITS)	UNITS
ITP 104x Internet Publishing Technologies	2
ITP 300x Database Web Development	3
ITP 301Lx Interactive Web Development	4
ITP 310x Design for User Experience	2
ITP 460x Web Application Project	4

ELECTIVES (ONE COURSE)	UNITS
ITP 404x Developing Web Services and Application Programming Interfaces	3
ITP 411x Interactive Multimedia Production	3
ITP 470x Information Technology Practicum	3
CSCI 455x Introduction to Programming Systems Design	4

Courses of Instruction

INFORMATION TECHNOLOGY PROGRAM (ITP)

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

ITP 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.

ITP 050x Microsoft Power Point (1) 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.

ITP 065x Microsoft Access (1)

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.

ITP 090x Introduction to Adobe Photoshop (2, FaSp) 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.

ITP 100x Information Technology for Business (2) 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.

ITP 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.

ITP 104x Internet Publishing Technologies (2, FaSpSm) 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.

ITP 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.

ITP 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.

ITP 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.

ITP 125Lx From Hackers to CEOs: Introduction to Information Security (2, FaSp) Introductory course in computer security. Fundamentals of information security management. Threats to information integrity. Ethical hacking concerns and practice. Policies and Procedures. Not available for major credit in Engineering.

ITP 150x Introduction to Visual BASIC (2) 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.

ITP 165x Introduction to C++ Programming (2) 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.

ITP 168x Introduction to MATLAB (2, FaSp) 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. (Duplicates credit in former ITP 068x.) *Recommended preparation:* MATH 118x or MATH 125.

ITP 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 104x.

ITP 209x Object Oriented Programming Using Java (3) 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 109x.

ITP 210x Multimedia Applications for Windows (2, FaSp) Focuses on creating powerful presentations with affordable multimedia hardware and software; integrates sound, video and animation into windowing environment. *Prerequisite:* ITP 101x .

ITP 211x Multimedia Authoring (2, FaSp) 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.

ITP 212x Digital Media Design and Management (3, FaSp) Design and composition as it applies to digital media, including web, CD, interactivity, and motion graphics. Media management, client relations, project and asset management.

ITP 215Lx 3D Modeling, Animation, and Special Effects (2, FaSp) Developing a 3D animation from modeling to rendering; Basics of surfacing, lighting, animation and modeling techniques. Advanced topics: compositing, particle systems, and character animation. Not available for major credit in engineering. *Recommended preparation:* knowledge of any 2D paint, drawing or CAD program.

ITP 216x Web Animation and Interactivity (2, FaSp) 2-D vector graphics for web and animation. Scripting techniques for interactivity. Action Script syntax, logic and control. *Recommended preparation:* basic computer knowledge.

ITP 220Lx Digital Video Editing and Motion Graphics (2, FaSp) Techniques for digital, non-linear video editing and compositing. Special video effects, rendering and compression for multimedia, the Web, and broadcast. Not available for major credit for EE or CSCI majors. *Recommended preparation:* general PC-based computer proficiency.

ITP 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 101x.

ITP 230x Video Game Quality Assurance (4, FaSp) Survey game software development through quality assurance and in-depth analysis of the development cycle with a focus on bug testing systems and methodologies.

ITP 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.

ITP 260x Internet Technologies (4, FaSp) Overview of emerging technologies on the Internet including multimedia components, networking, security tools, web-based databases, and wireless systems.

ITP 280 Video Game Production (4, FaSp) 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.

ITP 300x Database Web Development (3, FaSp) Fundamental theory and technologies for creating dynamic, database-driven Web sites: Structured Query Language. *Prerequisite:* ITP 104x; *recommended preparation:* ITP 204x.

ITP 301Lx Interactive Web Development (4, FaSp) Design, programming techniques for creating interactive, dynamic Web pages. Web development technologies and techniques include scripting fundamentals, Javascript, dynamic HTML, Actionscript, and Flash. Not available for major credit in Engineering. *Prerequisite:* ITP 104x.

ITP 304L Technologies for Building Online Political Campaigns (4, FaSp) Key technology components necessary in building a successful online political campaign. Fundamentals of implementing, marketing and managing an online political campaign.

ITP 305x Advanced 3D Modeling, Animation, and Special Effects (3, Sp) Advanced modeling, surfacing, and animation techniques as well as dynamics, scripting, and other advanced 3D automation procedures. Not available for major credit in engineering. *Prerequisite:* ARCH 207a or ITP 215Lx.

ITP 309x Developing Enterprise Applications Using Java (3) 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.

ITP 310Lx Design for User Experience (2, FaSp) Concepts, techniques, practices, workflows and tools for design from the perspective of user experience. Not available for major credit in Engineering. *Prerequisite:* ITP 104x.

ITP 315x 3D Character Animation (3) Advanced exploration of the process of bringing 3D characters to life from concept to model, and through production to finished performance. Not available for major credit in electrical engineering. *Prerequisite:* ITP 215Lx.

ITP 320Lx Enterprise Wide Information Systems (2, FaSpSm) The role Information Systems play in an organization. Integration of Business Processes by using Enterprise Resource Planning Systems (ERP). Not available for major credit in engineering.

ITP 321x Programming Enterprise Wide Information Systems (2, FaSp) 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 320Lx.

ITP 325x Ethical Hacking and Systems Defense (3, FaSp) Hacking from a defense perspective. Hacker ethics and laws. Penetration testing. Vulnerability assessment. Securing workstations, servers, and networks. Not available for major credit in Engineering. *Prerequisite:* ITP 125Lx.

ITP 330x Interactive 3-D Environments (3, FaSp) 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 211x.

ITP 345x Video Game Art and Animation (3) Create art and modeling for video games. Model, texture, light, and animate a sequence to be used in a video game engine. *Prerequisite:* ITP 215Lx.

ITP 357x Enterprise Network Design (3, Sp) Network technologies. Strategies for managing thousands of systems. Routers and managed switches. Integrated operating systems (IOS). Windows and Linux networking. Subnets. Not available for major credit in Engineering. *Prerequisite:* ITP 125Lx.

ITP 360x 3D Compositing and Visual Effects (3, Fa) Advanced techniques for 3D animation and visual effects development including 3D pre-visualization, match moving, dynamics, multi-pass rendering, and digital compositing. Not available for major credit in engineering. *Prerequisite:* ITP 215Lx.

ITP 370x Information Security Management (3, Sp) Management techniques for security projects. Security team management. Laws and regulations for information security. Disaster recovery. Security Audits. Not available for major credit in Engineering. *Prerequisite:* ITP 125Lx.

ITP 375x Digital Forensics (3, Fa) Forensic science techniques. Digital evidence preservation and presentation. Processes and methodologies for digital analysis. Not available for major credit in Engineering. *Prerequisite:* ITP 125Lx.

ITP 377x Linux System Administration (3, Fa) Installation, customization and administration of Linux in a networked environment. *Prerequisite:* ITP 225x.

ITP 380 Video Game Programming (4, FaSp) Underlying concepts and principles required for programming video games (topics include vectors, transformations, 3-D math, geometric primitives, matrices). *Prerequisite:* CSCI 102L or ITP 165x.

ITP 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.

ITP 383 Database Systems: Concepts, Design and Implementation (3, Sp) (Enroll in ISE 382)

ITP 385x IT Consulting and Professional Services (3, FaSp) Information Technology (IT) Consulting life cycle. Client relationships. Problem evaluation, solution development and implementation. Systems analysis and evaluation. Third party consulting. Not available for major credit in engineering. *Prerequisite:* ITP 101 or ITP 125.

ITP 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.

ITP 404x Developing Web Services and Application Programming Interfaces (3, Sp) Programming and scripting necessary to use and develop Web services and Application Programming Interface (APIs). Not available for major credit in Engineering. *Prerequisite:* ITP 301Lx.

ITP 411x Interactive Multimedia Production (3, FaSp) 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.

ITP 414x Seminar and 3D Portfolio Development (3, Sp) Advanced processes for developing 3D animation, showcasing skill sets, and qualifications for positions within the 3D animation industries; including demo reel, media, and website creation. Not available for major credit in engineering. *Prerequisite:* ITP 215Lx and ITP 305x or ITP 315x or ITP 360x.

ITP 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 300x.

ITP 422L Configuring Enterprise Resource Planning Systems (3, FaSp) Business process integration is the core advantage of using ERP systems. Analyze, configure, and test business processes for a company from the ground up. (Duplicates credit in former ITP 322.) *Prerequisite:* ITP 320Lx or ISE 583.

ITP 425x Web Application Security (4, Sp) Web application security techniques. eCommerce vulnerabilities. Online fraud. Solutions to spam and identity theft. Not available for major credit in Engineering. *Prerequisite:* CSCI 351 or ITP 301Lx or ITP 325x.

ITP 440x Enterprise Data Management (3) Advanced concepts in database management; design, customization, maintenance and management of a database in an enterprise environment. *Prerequisite:* IOM 435 or ITP 300.

ITP 454x Enterprise Resource Planning, Design, and Implementation (3, FaSp) An in-depth look at the process and requirements necessary to implement an Enterprise Resource Planning System (ERP). Students will set up a server system, implement an ERP system, then transfer and configure a database for a case company. *Prerequisite:* ITP 320x; *corequisite:* ACCT 454.

ITP 455Lx Enterprise Information Portals (3)

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 320Lx.

ITP 457 Network Security (4, Fa) 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 357x.

ITP 460x Web Application Project (4) Skills to plan, analyze, build, and launch professional Web sites for real clients. Includes project management, documentation, technology assessment, security, user interface and quality assurance. Not available for major credit in Engineering. Lecture: 3 hours; Lab: 3 hours. *Prerequisite:* ITP 301Lx.

ITP 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 102L; *corequisite:* CSCI 460.

ITP 470x Information Technology Practicum (1-4, max 8, FaSp5m) Independent technology project related to specific topics under the direction of a faculty member. Not available for graduate credit in engineering. *Recommended preparation:* appropriate 300-level course work to topic of study.

ITP 475x Advanced Digital Forensics (4, Sp)

Advanced forensic techniques. Live image analysis. Network level forensic investigation. Server forensic techniques. Deposition and trial. Not available for major credit in Engineering. *Prerequisite:* ITP 375x.

ITP 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 102L; *corequisite:* CSCI 480.

ITP 482L Engineering Database Applications (3)

Planning and implementation of engineering information systems that interface with a large database. Emphasis is placed on web-based data entry and retrieval. *Prerequisite:* ISE 382 or IOM 435.

ITP 484x Multiplayer Game Programming (4)

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 102L or ITP 165x.

ITP 485 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 102L, ITP 380.

ITP 486 Securing and Auditing Enterprise Resource Planning Systems (3, FaSp)

Management and technical issues related to the security of ERP systems. Students will audit ERP systems and apply appropriate security controls. *Prerequisite:* ITP 320Lx, ISE 382.

ITP 487Lx Data Warehouses and Business Intelligence (3)

Rigorous modeling process leading from data to decisions. Explores theory and practice of Data Warehouses. Deriving Business Intelligence for strategic enterprise management. Not available for major credit in engineering. *Prerequisite:* ITP 320Lx or ISE 382 or ISE 583.

ITP 488x Managing Supply Chains with Advanced Planning and Optimization (3)

Drivers and obstacles to the process of coordinating the flow of material/information along the logistics chain. Optimize the supply network, from raw materials to sales. Not available for major credit in engineering. *Prerequisite:* ISE 583 or ITP 320Lx.

ITP 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 391x.

ITP 499x Special Topics (2-4, max 8)

Recent developments in computers and data processing.

ITP 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.

Manufacturing Engineering

Ethel Percy Andrus
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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	
ISE 510	Advanced Computational Design and Manufacturing	3
ISE 511L	Computer Aided Manufacturing	3
ISE 517	Modern Enterprise Systems, or	
ISE 576	Industrial Ecology: Technology-Environment Interaction	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.

Multimedia and Creative Technologies

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

Elective Courses: 6-8 units

Students will choose two elective courses from the following list:

<i>Cinematic Arts</i>		
CTIN 483	Introduction to Game Development	4
CTIN 488	Game Design Workshop	4
<i>Engineering</i>		
EE 450	Introduction to Computer Networks	3
ITP 301Lx	Interactive Web Development, or	4
CSCI 351*	Programming and Multimedia on the World Wide Web	3

*Prerequisites waived if students are competent in programming.

<i>Journalism</i>		
JOUR 417	Online Journalism Management	2
<i>Fine Arts (Multimedia Design)</i>		
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

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 520	Computer Animation and Simulation	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 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	1-12
EE 554	Real Time Computer Systems	3
ISE 571	Human Factor Issues in Integrated Media Systems	3
ISE 575	Topics in Engineering Approaches to Music Cognition	3, max 6
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 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 Introduction to Game Development (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 Introduction to Digital Media Engineering	3
EE 469	Speech Recognition and Processing for Multimedia, or Immersive Audio Signal Processing	3
EE 519	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 6 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 CINEMATIC ARTS		UNITS
CTAN 452	Introduction to Computer Animation	2
CTIN 483	Introduction to Game Development	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

Product Development Engineering

Olin Hall of Engineering, 430
(213) 740-5353
FAX: (213) 740-8071
Email: mspde@usc.edu

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 interdisciplinary graduate degree program at USC jointly offered by the Aerospace and Mechanical Engineering and the Daniel J. Epstein Industrial and Systems Engineering (ISE) 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 SYSTEMS

REQUIRED COURSES (6 UNITS) UNITS

ISE 515	Engineering Project Management	3
ISE 544	Management of Engineering Teams	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 555	Invention and Technology Development	3
ISE 561	Economic Analysis of Engineering Projects	3

ISE 567	Collaborative Engineering Principles and Practice	3
ISE 576	Industrial Ecology: Technology-Environment Interaction	3
ISE 580	Advanced Concepts in Computer Simulation	3
ISE 585	Strategic Management of Technology	3
SAE 541	Systems Engineering Theory and Practice	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 588	Materials Selection	3
CE 550	Computer-Aided Engineering	3
CE 551	Computer-Aided Engineering Project	3
ISE 567	Collaborative Engineering Principles and Practice	3
ISE 576	Industrial Ecology: Technology-Environment Interaction	3
SAE 549	Systems Architecting	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

Systems Architecting and Engineering

Ethel Percy Andrus
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Program Director: Azad M. Madni, Ph.D.
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Program Co-director: F. Stan Settles, Ph.D.
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Associate Director: George Friedman, Ph.D.
Email: georgefriedman@yahoo.com

Associate Director: James Hines
Email: jhines@usc.edu

Associate Director: Scott Jackson
Email: jackessone@cox.net

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*)

Andrew and Erna Viterbi Chair in Communications: Solomon W. Golomb, Ph.D. (*Electrical Engineering, Mathematics*)

TRW Professor of Software Engineering: Barry Boehm, Ph.D. (*Computer Science, Industrial and Systems Engineering*)

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*); Azad M. Madni, Ph.D. (*Industrial and Systems Engineering*); Sami F. Masri, Ph.D. (*Civil Engineering, Mechanical Engineering*); Gerard Medioni, Ph.D. (*Computer Science*); Jerry M. Mendel, Ph.D. (*Electrical Engineering*); Najmedin Meshkati, Ph.D. (*Industrial and Systems Engineering, Civil Engineering*); James E. Moore, Ph.D. (*Industrial and Systems Engineering, Civil Engineering, Policy, Planning and Development*); Sheldon M. Ross, Ph.D. (*Industrial and Systems Engineering*); F. Stan Settles, Ph.D. (*Industrial and Systems Engineering, Astronautics*); Firdaus Udwardia, Ph.D. (*Civil Engineering, Mechanical Engineering*); Detlof von Winterfeldt (*Industrial and Systems Engineering, Policy, Planning, and Development*); Charles L. Weber, Ph.D. (*Electrical Engineering*); L. Carter Welford, Ph.D. (*Civil Engineering*); Alan Willner, Ph.D. (*Electrical Engineering*)

Associate Professor: Mansour Rahimi, Ph.D. (*Industrial and Systems Engineering*)

Adjunct Professor: Michael Mann, Ph.D. (*Industrial and Systems Engineering*)

Adjunct Associate Professors: James Hines; Thomas McKendree, Ph.D.; Marilee Wheaton

Research Professors: Malcolm R. Currie, Ph.D. (*Industrial and Systems Engineering*); Peter Will, Ph.D. (*Industrial and Systems Engineering*)

Professor of the Practice of Systems Architecting and Engineering: George Friedman, Ph.D. (*Industrial and Systems Engineering*)

Associate Professor of the Practice of Systems Architecting and Engineering: Kurt Palmer (*Industrial and Systems Engineering*)

Senior Lecturer: Geza Bottlik, Engineer (*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*)

Honor Societies

Omega Alpha Association

Omega Alpha Association is the systems engineering honor society. The advisor is Professor Stan Settles, (213) 740-0263.

Degree Requirements

Master of Science in Systems Architecting 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 architecting 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 Viterbi School of Engineering, the Master of Science in systems architecting 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 architecting 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 6 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 Architecting 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, or
ISE 563	Financial Engineering, or
SAE 560	Economic Considerations
	for Systems Engineering
SAE 541	Systems Engineering
	Theory and Practice
SAE 549	Systems Architecting
	3
One design-related course approved	
by the director	3

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

Technical Management Area: Take one course (3 units) from the following:

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*	Global Businesses and Markets: Strategies Enabled by Technology	3
IOM 580*	Project Management	3
ISE 515	Engineering Product Management	3
ISE 517	Modern Enterprise Systems	3
ISE 544	Management of Engineering Teams	3
ISE 562	Value and Decision Theory	3
ISE 585	Strategic Management of Technology	3
MOR 561*	Strategies in High-Tech Businesses	3
SAE 550	Systems Architecting and the Political Process	3

*USC Marshall School of Business course.

General Technical Area: Take one course (3 units) from the following:

CSCI 510	Software Management and Economics	3
CSCI 577ab	Software Engineering	4-4
IOM 535*	Database Management	3
ISE 580	Advanced Concepts in Computer Simulation	3
SAE 542	Advanced Topics in Systems Engineering	3
SAE 543	Case Studies in Systems Engineering and Management	3
SAE 550	Systems Architecting and the Political Process	3
SAE 551	Lean Operations	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 503, AME 504, AME 521, AME 532a, AME 544, AME 548, AME 560, 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

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 544, ISE 562, ISE 580, ISE 585; SAE 541, SAE 550

Integrated Media Systems: EE 450, EE 469, EE 522, EE 555, EE 569, EE 596; CSCI 480, CSCI 551, CSCI 574, CSCI 576, CSCI 585, CSCI 588

Manufacturing Systems: AME 588; EE 561ab; ISE 511, ISE 514, ISE 516, ISE 517, ISE 544, ISE 570

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; EE 554, EE 557; ISE 544, ISE 562, ISE 564

Systems: EE 598; ISE 515, ISE 520, ISE 525, ISE 527, ISE 528, ISE 532, ISE 535, ISE 536, ISE 538, ISE 544, ISE 562, ISE 580, ISE 585; SAE 541, SAE 542

Graduate Certificate in Systems Architecting and Engineering

The graduate certificate in systems architecting 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 Architecting and Engineering.

REQUIRED COURSES – CHOOSE FOUR		UNITS
ISE 460	Engineering Economy, or	
ISE 561	Economic Analysis of Engineering Projects, or	
SAE 560	Economic Considerations for Systems Engineering	3
ISE 515	Engineering Project Management	3
ISE 544	Management of Engineering Teams	3
SAE 541	Systems Engineering Theory and Practice	3
SAE 542	Advanced Topics in Systems Engineering	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 Architecting and Engineering.

All programs of study will be approved by the director of the Systems Architecting and Engineering program.

Graduate Certificate in Network Centric Systems

This 15-unit graduate certificate is jointly sponsored by the Epstein Industrial and Systems Engineering, Hsieh Electrical Engineering and Computer Science departments, and administered by the Epstein ISE Department. This certificate is designed for practicing engineers engaged in the creation and design of complex innovative network centric 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 Computer Science, Electrical Engineering or Systems Architecting Engineering with departmental approval.

REQUIRED COURSES		UNITS
SAE 574	Net-centric Systems Architecting and Engineering	3
Choose 4 courses from one area of emphasis: 12		
<i>Computer Science Emphasis</i>		
Required CSCI course		
CSCI 551	Computer Communications	3
CSCI Electives (choose three courses, 9 units)		
CSCI 530	Security Systems	4
CSCI 531	Applied Cryptography	3
CSCI 546	Intelligent Embedded Systems	3
CSCI 555	Advanced Operating Systems	3

CSCI 556	Introduction to Cryptography	3
CSCI 558L	Internetworking and Distributed Systems Laboratory	3
CSCI 561	Foundations of Artificial Intelligence	3
CSCI 573	Advanced Artificial Intelligence	3
CSCI 576	Multimedia Systems Design	3
CSCI 585	Database Systems	3

Electrical Engineering Emphasis

Required EE course

EE 535	Mobile Communications	3
EE Electives (choose three courses, 9 units)		
EE 538	Spread Spectrum Systems	3
EE 541	Radio Frequency Filter Design	3
EE 544	Radio Frequency Systems and Hardware	3
EE 550	Design and Analysis of Computer Communication Networks	3
EE 555	Broadband Network Architectures	3
EE 562ab	Random Processes in Engineering	3-3
EE 564	Communication Theory	3
EE 567	Communication Systems	3
EE 579	Wireless and Mobile Networks Design and Laboratory	3
EE 663	Satellite Communications	3
EE 666	Data Communication	3

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Courses of Instruction

SYSTEMS ARCHITECTING AND ENGINEERING (SAE)

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

SAE 496 Systems Engineering Through Motorsports (3, FaSp) Applied systems architecting, engineering and management to motorsports from design to validation and verification; venues include drag racing, grand prix Formula SAE racing, DARPA Challenges.

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

SAE 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. (Duplicates credit in former ISE 541).

SAE 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. (Duplicates credit in former ISE 542). *Prerequisite:* SAE 541.

SAE 543 Case Studies in Systems Engineering and Management (3, FaSp) Real-world case studies in DoD, NASA, and commercial arenas, employing new methodologies to cover the fundamental positive and negative development learning principles of systems engineering. *Prerequisite:* SAE 541, SAE 549.

SAE 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.

SAE 550 Systems Architecting and the Political Process (3) 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. (Duplicates credit in former ISE 550). *Recommended preparation:* two years of work experience.

SAE 551 Lean Operations (3, Sp) Study of lean principles and practices as applied to automotive, aerospace and other industries.

SAE 560 Economic Considerations for Systems Engineering (3) Impact of economic factors for systems architects and engineers, tools for understanding these factors, fundamental quantitative analysis of cash flow, life-cost estimating for systems and software engineering.

SAE 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.

SAE 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.

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

SAE 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 architecting and engineering.