USC Viterbi School of Engineering

Faculty and undergraduates from the USC Viterbi School of Engineering show their spirit in the Piazza Trilussa in Trastevere, Rome as part of the school's summer European program. While taking two major-related courses and exploring the local environs, students learn more about other cultures as well as gain perspective on technology issues in other countries. As evidenced in this photo, a growing number of women are entering the engineering field; 38 percent of the Viterbi School's 2013 freshman class was female, which is almost exactly twice the national average for undergraduate engineering enrollments.

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, 202 full-time, tenure track faculty (and more than 330 total full-time faculty) serve about 2,800 undergraduates in major and minor programs and almost 4,900 graduate students, utilizing extensive and technically advanced laboratories, classrooms and live interactive high-speed Internet broadcast systems. Government and industry annually fund nearly $181 million worth of research.

USC Viterbi is innovative, elite and internationally recognized for creating new models of education, research and commercialization that are firmly rooted in real world needs. The school's first priorities are the education of outstanding students and the pursuit and publication of new 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, ambition and character that mark the true academic and professional engineer – to serve California, the nation and the world. At USC Viterbi, we call this the enabling power of Engineering+.

Viterbi undergraduate support programs complement and strengthen the academic experience, enhancing both depth and scope. 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 produces a steadily growing core of doctoral graduates across the disciplines. 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; Chemical Engineering; Civil Engineering; Computer Engineering and Computer Science; Computer Science; Computer Science/Business Administration (with the Marshall School of Business); Computer Science (Games); Electrical Engineering; Environmental Engineering; Industrial and Systems Engineering; Mechanical Engineering; and Physics/Computer Science (with the Dornsife College of Letters, Arts and Sciences).

Minor programs are offered in: Applied Computer Security; Astronautical Engineering; Computer and Digital Forensics; Computer Programming; Computer Science; Construction Planning and Management (with the Price School of Public Policy); Craniofacial and Dental Technology (with the Herman Ostrow School of Dentistry and the Dornsife College of Letters, Arts and Sciences); Engineering Management; Enterprise Information Systems; Environmental Engineering; Innovation: The Digital Entrepreneur (with the Marshall School of Business); Materials Science; Mobile App Development; Petroleum Engineering; 3-D Animation; Technology Commercialization (with the Marshall School of Business); Video Game Design and Management; Video Game Programming; Web Technologies and Applications.

Graduate curricula leading to the Master of Science in: Aerospace Engineering; Aerospace and Mechanical Engineering (Computational Fluid and Solid Mechanics); Aerospace and Mechanical Engineering (Dynamics and Control); Analytics; Astronautical Engineering; Biomedical Engineering; Biomedical Engineering (Medical Imaging and Imaging Informatics); Chemical Engineering; Civil Engineering; Civil Engineering (Transportation Engineering); Civil Engineering (Transportation Systems); Civil Engineering (Water and Waste Management); Computer Engineering; Computer Science; Computer Science (Computer Networks); Computer Science (Computer Security); Computer Science (Data Science); Computer Science (Game Development); Computer Science (High Performance Computing and Simulations); Computer Science (Intelligent Robotics); Computer Science (Multimedia and Creative Technologies); Computer Science (Scientists and Engineers); Computer Science (Software Engineering); Data Informatics; Electrical Engineering; Electrical Engineering (Computer Networks); Electrical Engineering (Electric Power); Electrical Engineering (Multimedia and Creative Technologies); Electrical Engineering (Telecommunications); Electrical Engineering (VLSI Design); Electrical Engineering (Wireless Health Technology); Electrical Engineering (Wireless Networks); Engineering Management; Environmental Engineering; Financial Engineering; Global Supply Chain Management (with the Marshall School of Business); Green Technologies; Health Systems Management Engineering (with the Price School of Public Policy, not currently accepting applications); Industrial and Systems Engineering; Manufacturing Engineering; Materials Engineering; Materials Science; Mechanical Engineering; Mechanical Engineering (Energy Conversion); Mechanical Engineering (Nuclear Power); Medical Device and Diagnostic Engineering; Operations Research Engineering; Petroleum Engineering; Petroleum Engineering (Geoscience Technologies); Petroleum Engineering (Smart Oilfield Technologies); Product Development Engineering; and Systems Architecting and Engineering.

Graduate curricula leading to the Master of Construction Management and Master of Cyber Security.

Graduate curricula leading to dual degrees in: Master of Science Aerospace Engineering / Master of Science Engineering Management, Master of Science Electrical Engineering / Master of Science Engineering Management, Master of Science Industrial and Systems Engineering / Master of Business Administration and Master of Science Mechanical Engineering / Master of Science Engineering Management.

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; Health, Technology and Engineering (with the Keck School of Medicine); Network Centric Systems; Smart Oilfield Technologies; Software Architecture; Systems Architecting and Engineering; and Transportation Systems.

Undergraduate Program Accreditation

The Bachelor of Science degrees in aerospace engineering, astronautical engineering, biomedical engineering, chemical engineering, civil engineering, computer engineering and computer science, electrical engineering, environmental engineering, industrial and systems engineering, and mechanical engineering are accredited by the Engineering Accreditation Commission of ABET, abet.org. *The Bachelor of Science degrees in computer engineering and computer science and in computer science are accredited by the Computing Accreditation Commission of ABET,* abet.org.

Undergraduate Program Student Outcomes

By the time of graduation from Bachelor of Science degree programs accredited by the Engineering Accreditation Commission of ABET, students will develop at least the following abilities and knowledge:

- an ability to apply knowledge of mathematics, science and engineering

- an ability to design and conduct experiments, as well as to analyze and interpret data

- an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

- an ability to function on multidisciplinary teams

- an ability to identify, formulate and solve engineering problems

- an understanding of professional and ethical responsibility

- an ability to communicate effectively

- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context

- a recognition of the need for, and an ability to engage in life-long learning

- a knowledge of contemporary issues

- an ability to use the techniques, skills and modern engineering tools necessary for engineering practice

By the time of graduation from Bachelor of Science degree programs accredited by the Computing Accreditation Commission of ABET, students will develop at least the following abilities and knowledge:

- an ability to apply knowledge of mathematics appropriate to the program's student outcomes and to the discipline

- an ability to analyze a problem, and identify and define the computing requirements appropriate to its solution

- an ability to design, implement and evaluate a computer-based system, process, component or program to meet desired needs

- ability to function effectively on teams to accomplish a common goal

- an understanding of professional, ethical, legal, security and social issues and responsibilities

- an ability to communicate effectively with a range of audiences

- ability to analyze the local and global impact of computing on individuals, organizations and society

- recognition of the need for and an ability to engage in continuing professional development

- an ability to use current techniques, skills and tools necessary for computing practice

- an ability to apply mathematical foundations, algorithmic principles and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the trade-offs involved in design choices

- an ability to apply design and development principles in the construction of software systems of varying complexity

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 for the Viterbi School. 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 in Ronald Tutor Hall 110. Approval is granted on the basis of academic performance at USC and in the required prerequisite courses in the Viterbi School within a specific number of semesters.

Non-engineering students may complete a maximum of four engineering courses. No further engineering courses may be taken unless admission 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: aerospace engineering, 130 units; biomedical engineering with an emphasis in electrical engineering, 133 units; biomedical engineering with an emphasis in mechanical engineering, 132 units; chemical engineering, 129 units; chemical engineering with an emphasis in biochemical engineering, 133 units; chemical engineering with an emphasis in environmental engineering, 132 units; chemical engineering with an emphasis in nanotechnology, 128 units; chemical engineering with an emphasis in petroleum engineering, 133 units; chemical engineering with an emphasis in polymer/materials science engineering, 133 units; civil engineering, 131 units; civil engineering with an emphasis in building science, 135-36 units; civil engineering with an emphasis in environmental engineering, 129-130 units; civil engineering with an emphasis in structural engineering, 131 units; electrical engineering, 131 units; environmental engineering, 131-134 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 The USC Core **and** the General Education Program for more information. .

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 or the lower-division writing requirement for USC; 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, astronautical and mechanical engineering complete Social Issues and the lower-division writing requirement in different semesters.

In all other respects, students in the Viterbi School of Engineering must satisfy the general education requirements as described on The USC Core page **and** the General Education Program page.

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 applied toward the major 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 adviser 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 John Hubbard Hall 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 fee determined by the Academic Review Office 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 and Women in Engineering Office (WIE)

The Center for Engineering Diversity (CED) provides a variety of services for historically underrepresented students in engineering (African-American, Hispanic and Native American students, including women). Prior to their first semester in Viterbi, freshmen can participate in a four-week summer residential program (Summer Institute).

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

The Women in Engineering Office (WIE) offers professional, academic and co-curricular support to the women of the Viterbi School. The goal of the Viterbi Women in Engineering Office is to recognize the unique challenges that female engineering students will face, provide resources and overall support to address these challenges, and allow our female students to find academic and personal success during their Viterbi career and beyond.

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 designed to enhance undergraduate engineering student life experiences outside the classroom. The KIUEL Programming Board implements programs around leadership, service learning and globalization, and cross-disciplinary learning. Past KIUEL events have included the KIUEL Weekend for Leaders, the KIUEL Showcase and the Senior Design Expo. 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 wages 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. Continuing students can use the same application form to apply for the award starting in their sophomore year.

First Year Excellence

The First Year Excellence (FYE) program helps first-year students develop strong connections to the university and the Viterbi School of Engineering. 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 Series help guide students as they explore engineering. Academic advisers work with all freshman students to ensure they are on track academically and to assist with acclimating to college life and USC. Free tutoring, group-led supplemental instruction sessions, workshops and seminars on time management and networking with faculty are available to students to assist them in accomplishing their goals.

Viterbi Career Services

The Viterbi School of Engineering provides extensive career services to all 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., Chevron Corporation, Cisco Systems, Inc., Clark Construction, Google, 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, Raytheon, 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 applies to the Viterbi School of Engineering as a junior and, if admitted, completes the remaining requirements for a B.S. degree typically within two years. After degree requirements for both schools 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 Florence, London, Paris, Madrid, Rome or another location that 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 International Exchange Program gives undergraduate students the opportunity to broaden their exposure to the global context of engineering theory and practice by spending a semester 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 Viterbi 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), and Upsilon Pi Epsilon (computer science).

Minor in Technology Commercialization

This interdisciplinary minor includes courses from both the business and engineering schools and provides education in the economic, technological and entrepreneurial aspects of commercializing new technologies. The minor is designed for students from a range of backgrounds (e.g., majors in engineering, life sciences or business) who are interested in starting their own technology-based ventures, working for technology-based start-up companies or pursuing corporate careers that may involve the commercialization of new technologies. In the minor, students learn about conceptualizing, developing, and managing new, technology-based ventures and projects.

To enroll, students must have completed a minimum of 32 units of college-level course work and have a minimum overall GPA of 2.75. To complete the minor, students are required to complete the two required courses (7 units) and enough elective courses to achieve a total of 16 units outside of their major. Business majors thus require 23

total units and other majors 16 total units to complete the minor.

REQUIRED COURSES		UNITS
BAEP 452	Feasibility Analysis	4
BUAD 301	Technical Entrepreneurship	3
ELECTIVE COURSES		UNITS
ACCT 410x	Foundations of Accounting	4
BAEP 454	Venture Initiation: Launching and Scaling Your Startup	4
BAEP 460	Seminar in Entrepreneurship	2-4
BAEP 470	The Entrepreneurial Mindset — Taking the Leap	2
BME 416	Development and Regulation of Medical Products	3
BUAD 307	Marketing Fundamentals, or	
MKT 385x	Marketing of Creative Disruption and Innovation	4
CE 473	Engineering Law, Finance and Ethics, or	
ENGR 509	Patent Law for Scientists and Engineers	3
ENGR 493x	Dean's Seminar in Entrepreneurship	2
ISE 344	Engineering Team Management	3
ISE 440	Work, Technology, and Organization	3
ISE 460	Engineering Economy	3
ITP 310x	Design for User Experience	2
ITP 466	Building the High Tech Startup	4
ITP 476	Technologies for Interactive Marketing	4
MKT 445	New Product Development and Branding	4

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, data informatics, electrical engineering, 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, product development engineering, sustainable infrastructure systems, and systems architecting and engineering; and the Master's degree in construction management and in cyber security. 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

To qualify for admission, applicants are expected to present strong academic records and show superior accomplishment in their engineering and related 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. Some programs also require letters of recommendation and a statement of purpose. Doctor of Philosophy 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 curriculum for the bachelor's degree. 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 Office of Graduate Admission from the schools attended. If the Graduate Record Examinations general and subject tests, as well as the TOEFL or IELTS exams, have been taken the scores should be sent to the Office of Graduate 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. (Credit by exam 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, excluding any 590 courses. 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 the Requirements for Graduation page.

General Requirements for the Master of Science

Residence Requirements

Viterbi students are allowed up to five years to earn a master's degree. Depending on the specific degree, the typical time required varies from between one and one-half to two years for students in M.S. programs on-campus to three years for M.S. students completing their degrees online via DEN@Viterbi. Master's degrees other than the Master of Science typically require more course work, and may take more time to complete.

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 the Office of Degree Progress and 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 the assigned 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 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 adviser or refer to the department Website 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.

Course Selection

There are two program options for the master's degree, one with a thesis and the other without. 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 without Thesis

The minimum requirement is 27 units; 18 of these units must be at the 500 level and at least 18 units must be in the major department and closely related departments. Prior department approval is required for all non-major courses. Specific requirements are listed under each department.

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.

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 adviser. (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. Units of 594ab Master's Thesis may not be converted to units of 590 Directed Research.

A student readmitted to candidacy by petition to the Graduate School 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 Graduate 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**;** Grade Point Average Requirements*; and the Website of the Office of Graduate and Professional Programs (GAPP) at* viterbi.usc.edu/gapp.

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 must consult with the faculty adviser for formal written permission to take courses outside the major department for degree credit.

A copy of the faculty adviser'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 student's academic department.

Second Master's Degree

A graduate student who already holds a master's degree from USC may apply a limited number of previously earned units toward the second master's degree.

The maximum number of units allowed for transfer is: 4 units in degree programs requiring 24-32 units; 8 units in programs requiring 33-40 units; 12 units in programs requiring 41 or more units. 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.

For students who earned their first master's degree at another institution, no course work may be repeated from the first program of study and no unit credit from the first program of study may be counted toward the second master's degree.

General Requirements for the Master of Engineering Degree

The Viterbi School does not currently offer degree programs with the Master of Engineering designation.

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 also intended to fulfill a growing need in 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, materials science, mechanical engineering and petroleum engineering.

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 qualifying exam 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 qualifying exam 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. 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 adviser 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 Graduate 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 qualifying exam 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 the Office of Degree Progress.

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 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 adviser or refer to the department Website 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 qualifying exam committee. Transfer units are subject to approval by the Office of Degree Progress (for course work taken at institutions in the United States) or by the Office of Graduate Admission (for course work taken at institutions outside the United States) and by the qualifying exam 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.

Qualifying Exam Committee

The Ph.D. student's program of study is supervised by the qualifying exam 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. Reporting the screening procedures and forming the qualifying exam committee are accomplished by filing the appropriate forms obtainable from the Graduate School Website, usc.edu/schools/GraduateSchool.

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 qualifying exam committee decides the nature of the

qualifying examinations (both oral and written portions) according to the policies applicable in each department.

If not otherwise enrolled, a student must enroll in GRSC 800 during the semester in which the qualifying examination is to be taken. Students are strongly encouraged to take the qualifying examination during the first semester in which they are enrolled in GRSC 800, and should not enroll in more than two semesters of GRSC 800 before taking the qualifying examination.

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 Graduate School 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 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 upload the dissertation to the Graduate School.

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**;** Grade Point Average Requirements*; and the Website of the Office of Graduate and Professional Programs (GAPP) at* viterbi.usc.edu/gapp.

Special Educational Opportunities

DEN@Viterbi

Established in 1972, DEN@Viterbi, the USC Viterbi School of Engineering's online delivery system 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. DEN@Viterbi students enrolled around the world are pursuing over 40 graduate degree programs online – more choices than at any other research university. DEN@Viterbi breaks down geographical and scheduling barriers, allowing students to take classes anytime and anywhere, with the option for live interactivity. DEN@Viterbi students receive support from administrative and technical staff, and enjoy access to all services 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@Viterbi. This valuable study aid enables students to review lectures throughout the semester.

For more information about the Viterbi School graduate programs and DEN@Viterbi, visit viterbi.usc.edu/gapp.

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 adviser 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, Fa) *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 345 Principles and Practices of Global Innovation (3, Sp) Learner-centered, cross-cultural, technology-enabled approaches to principles and industrial practices leveraging cultural diversity to inspire innovations for competitive global markets. Requires an extended semester of 22 weeks, including 2-week overseas project in early summer.

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 401x Communicating Science and Engineering to Children (3, max 6, FaSp) Engineering students communicate their knowledge, collaborate constructively with peers, and inspire underserved children to develop a curiosity and persistence for science and engineering. Open only to junior and senior engineering students.

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 (2, max 4, FaSpSm) 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 credit to master's students.

ENGR 503x Oral Communication Skills for Engineering Ph.D. Students (2, max 4, FaSpSm) 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 to master's students.

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 509 Patent Law for Scientists and Engineers (3, Sp) *Tools for engineering and science graduate students to make informed decisions about obtaining and enforcing patent protection for their future inventions: validity, infringement, unenforceability. Recommended preparation:* EE 682 or ISE 565.

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.

ENGR 599 Special Topics (2-4, max 9) Current developments in the field of engineering; topics to be selected each semester.

Aerospace and Mechanical Engineering

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

Faculty and Business Office
Olin Hall of Engineering
Room 430
(213) 740-8762
FAX: (213) 740-8071
Email: ame@usc.edu
Chair: Geoffrey R. Spedding, Ph.D.*

Faculty

Choong Hoon Cho Chair in Aerospace and Mechanical Engineering: Michael Kassner, Ph.D.

Philip and Cayley MacDonald Early Career Chair: Andrea Hodge, Ph.D.

William E. Leonhard Professor of Engineering: Fokion Egolfopoulos, Ph.D.

Gordon S. Marshall Professor of Engineering Technology: Roger Ghanem, Ph.D. (Civil and Environmental Engineering)

Zohrab A. Kaprielian Fellow in Engineering: Eva Kanso, Ph.D.

Professors: Charles Campbell, Ph.D.; Julian Domaradzki, Ph.D.**; Fokion Egolfopoulos, Ph.D.*; Henryk Flashner, Ph.D.; Roger Ghanem, Ph.D. (Civil and Environmental Engineering); Yan Jin, Ph.D.; Michael E. Kassner, Ph.D. (Materials Science); Paul K. Newton, Ph.D.; Larry G. Redekopp, Ph.D.*; Paul Ronney, Ph.D.; Satwindar S. Sadhal, Ph.D.; Geoffrey Spedding, Ph.D.*; Firdaus E. Udwadia, Ph.D. (Civil and Environmental Engineering, Data Science and Operations, Systems Architecting and Engineering and Mathematics); Bingen Yang, Ph.D.

Associate Professors: Andrea Hodge, Ph.D.; Eva Kanso, Ph.D.; Geoffrey R. Shiflett, Ph.D.*

Assistant Professors: Veronica Eliasson, Ph.D.; Nestor Perez-Arancibia, Ph.D.

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

Senior Lecturers: Oliver Franke, Ph.D.; Takahiro Sakai, Ph.D.

Lecturers: Charles Radovich, Ph.D.; Yann Staelens, Ph.D.; David Wilcox, Ph.D.

Research Associate Professor: Adam Fincham, Ph.D.

Research Associate: Anita Penkova, Ph.D.

Joint Appointments: Yong Chen, Ph.D. (Industrial and Systems Engineering); Daniel Erwin, Ph.D.* (Astronautics); Mike Gruntman, Ph.D. (Astronautics); Petros Ioannou, Ph.D. (Electrical Engineering – Systems); Berok Khoshnevis, Ph.D. (Industrial and Systems Engineering); Joseph Kunc, Ph.D. (Astronautics, Physics); Stephen C-Y Lu, Ph.D. (Industrial and Systems Engineering); Sami F. Masri, Ph.D. (Civil and Environmental Engineering); Steven Nutt, Ph.D. (Materials Science); Constantinos Sioutas, Ph.D. (Civil and Environmental Engineering); Francisco Valero-Cuevas, Ph.D. (Biomedical Engineering)

Emeritus Professors: Ron Blackwelder, Ph.D.*; Fred Browand, 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 Mission

The degree programs of the Department of Aerospace and Mechanical Engineering provide the educational foundation for success in all walks of life whether or not one's career path includes employment as a professional engineer, work in a field outside of engineering, or pursuit of further education.

Undergraduate Program Educational Objectives

Graduates of the undergraduate programs in Aerospace and Mechanical Engineering are expected to attain the following objectives within a few years after graduation:

- Work as professionals within engineering or a related area in both small- and large-scale businesses;

- Pursue further education through graduate school or professional development courses; and

- Become leaders within their chosen profession whether it be industry, academia or service.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Aerospace Engineering prepares graduates to have a knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control. The program also prepares graduates to have design competence that includes integration of aeronautical topics.

The program leading to a Bachelor of Science in Mechanical Engineering requires students to apply principles of engineering, basic science and mathematics (including multivariate calculus and differential equations); to model, analyze, design and realize physical systems, components or processes; and prepares students to work professionally in both thermal and mechanical systems areas.

Aerospace Engineering Degrees

Bachelor of Science in Aerospace Engineering

The requirement for this degree is 130 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied toward the major, regardless of the department in which the courses are taken. See the common requirements for undergraduate degrees section.

composition/writing requirement		Units
WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	3

General Education		units
General education+		20

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

Major requirements		units
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 231L	Mechanical Behavior of Materials	3
AME 261	Basic Flight Mechanics	4
AME 301	Dynamics	3
AME 302	Dynamic Systems	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 436	Energy and Propulsion	3
AME 441aL	Senior Projects Laboratory	3
AME 451	Linear Control Systems I	3
AME 481	Aircraft Design	4

Astronautics

ASTE 280	Foundations of Astronautical Engineering	3

Major Electives	units
AME core electives**	3
Technical electives***	6
Total units:	130

* Satisfies GE Category III requirement.

** 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.

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 advanced computational technical electives provide practical examples using existing numerical programs to simulate structures, heat transfer and fluid flows as well as commercial mathematical packages for analyzing data and simulations.

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 (21 units)		Units
AME 404	Computational Solutions to Engineering Problems	3
AME 509	Applied Elasticity, or	
CE 507	Mechanics of Solids I	3
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3
AME 530a	Dynamics of Incompressible Fluids	3
AME 535a	Introduction to Computational Fluid Mechanics	3
CE 529a	Finite Element Analysis	3

Select a computational technical elective from the following list or another approved by a graduate adviser: 3 units.

Computational Technical Elective (3 units)		units
AME 415	Turbine Design and Analysis	3
AME 535b	Introduction to Computational Fluid Mechanics	3
ASTE 545	Computational Techniques in Rarefied Gas Dynamics	3
CE 529b	Finite Element Analysis	3
CE 551	Computer-Aided Engineering Project	3
MASC 575	Basics of Atomistic Simulation of Materials	3
MASC 576	Molecular Dynamics Simulations of Materials and Processes	3
MATH 504ab	Numerical Solution of Ordinary and Partial Differential Equations	3

Select a technical elective from the following list or other electives approved by a graduate adviser: 3 units.

Technical electives (3 Units)		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
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 adviser 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 adviser. 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

Master of Science in Systems Architecting and Engineering

See the listing under Systems Architecting and Engineering.

Master of Science in Aerospace Engineering/Master of Science in Engineering Management

The department of Aerospace and Mechanical Engineering in conjunction with the Daniel J. Epstein Department of Industrial and Systems Engineering offers programs leading to the degree of Master of Science in Aerospace Engineering/Master of Science in Engineering Management. This program is designed for graduate aerospace engineers whose career objectives lead to increasing technical management responsibilities.

In addition to the general requirements of the Viterbi School of Engineering, the dual degree of Master of Science in Aerospace Engineering/Master of Science in Engineering Management is also subject to the following requirements:

**All applicants must meet the admission requirements of both the Department of Aerospace and Mechanical Engineering and the Department of Industrial and Systems Engineering;
A minimum of 48 units is required;
A minimum of 18 units must be graduate-level course work in AME, approved by an AME graduate student adviser;
A minimum of 18 units must be graduate level course work in ISE, approved by the ISE Engineering Management graduate student adviser and chosen from the course list under Master of Science in Engineering Management;
A minimum additional 12 units of acceptable course work must be chosen with the consent of the ISE Engineering Management graduate student adviser to form a coherent program.**

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 qualifying exam 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.

Mechanical Engineering Degrees

The department offers a Bachelor of Science degree in Mechanical Engineering. Additionally, petroleum engineering exists as an emphasis within the mechanical engineering program. An area of emphasis appears in parenthesis after the primary major name on the transcript.

Bachelor of Science in Mechanical Engineering

The requirement for the degree is 128 units. A cumulative grade point average of C (2.0) is

required in all upper division courses applied toward the major, regardless of the department in which the courses are taken. See the common requirements for undergraduate degrees section.

Composition/writing requirement		Units
WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	3

General Education	units
General education+	20

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
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
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 302	Dynamic Systems	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

Materials Science

MASC 310	Materials Behavior and Processing	3

Major Electives	units
AME core electives**	3
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

Emphasis in Petroleum Engineering

The requirement for the degree with an emphasis in petroleum engineering 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.

composition/writing requirement		Units
WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	3

General Education	units
General education+	20

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, 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

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

major requirements		units
Aerospace and Mechanical Engineering		
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 302	Dynamic Systems	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

Petroleum Engineering		
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
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 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 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.

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 adviser about an area of concentration and draw up a plan of study, which must be approved by the adviser. 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 Mechanical Engineering (Nuclear Power)

The program offers the degree of Master of Science in mechanical engineering with specialization in nuclear power. It is structured so that students who have all the prerequisites can complete the entire program through distance education. It is intended for students with an undergraduate degree in engineering. However, students with a physics and/or chemistry background can be accommodated with the completion of certain prerequisites.

fundamental		UNITS
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3

Core		units
AME 534	Nuclear Thermal-Hydraulics	3
AME 581	Introduction to Nuclear Engineering	3
AME 582	Nuclear Reactor Physics	3
AME 583	Effects of Radiation on Health	3
CE 571	Nuclear Safety and Security: Human Performance and Safety Culture	3

Electives — Choose 6 units		units
AME 457	Engineering Fluid Dynamics	3
AME 515	Advanced Problems in Heat Conduction	3
AME 516	Convection Processes	3
AME 517	Radiation Heat Transfer	3
AME 530a	Dynamics of Incompressible Fluids	3
AME 530b	Dynamics of Incompressible Fluids	3
AME 533	Multi-Phase Flows	3
AME 535a	Introduction to Computational Fluid Mechanics	3
AME 577	Survey of Energy and Power for a Sustainable Future	3
AME 578	Modern Alternative Energy Conversion Devices	3
CHE 502	Numerical Methods for Diffusive and Convective Transport	3
EE 526	Renewable Energy in Power Systems	3
ENE 516	Hazardous Waste Management	3
Total units:		27

Master of Science in Mechanical Engineering (Energy Conversion)

See Sustainable Infrastructure Systems.

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.

Master of Science in Mechanical Engineering/Master of Science in Engineering Management

The department of Aerospace and Mechanical Engineering in conjunction with the Daniel J. Epstein Department of Industrial and Systems Engineering offers programs leading to the degree of Master of Science in Mechanical Engineering/Master of Science in Engineering Management. This program is designed for graduate mechanical engineers whose career objectives lead to increasing technical management responsibilities.

In addition to the general requirements of the Viterbi School of Engineering, the dual degree of Master of Science in Mechanical Engineering/Master of Science in Engineering Management is also subject to the following requirements:

All applicants must meet the admission requirements of both the Department of Aerospace and Mechanical Engineering and the Department of Industrial and Systems Engineering;
A minimum of 48 units is required;
A minimum of 18 units must be graduate level course work in AME, approved by an AME graduate student adviser;
A minimum of 18 units must be graduate level course work in ISE, approved by the ISE Engineering Management graduate student adviser and chosen from the course list under Master of Science in Engineering Management;
A minimum additional 12 units of acceptable course work must be chosen with the consent of the ISE Engineering Management graduate student adviser to form a coherent program.

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, FaSp) *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 231L Mechanical Behavior of Materials (3, Sp) *Material properties of metals, ceramics, and composites; stress-strain relationships; microstructural characteristics; fracture, fatigue, and creep; effects of processing.* Corequisite: AME 204.

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, FaSp) 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.* Prerequisite: MATH 245; recommended preparation: AME 309 or CE 309; AME 301 or CE 325.

AME 303 Dynamics of Machinery (3, FaSpSm) *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 235.

AME 305 Mechanical Design (3, Fa) *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 Analyses for Aero-Mechanical Design (3, FaSpSm) *Introduction to the finite element method; practical application of computer analysis tools for structural analysis and design.* Prerequisite: AME 204; corequisite: AME 301.

AME 309 Dynamics of Fluids (4, FaSp) *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 and transient conditions; heat exchangers.* 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, Irregular) Shear and bending in symmetrical and unsymmetrical sections; torsion, column, and thin sheet analysis and design, including plastic failures and open section crippling.

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, FaSp) *Design of mechanical systems using advanced graphics techniques; computer-aided drafting, design optimization, elements of computer graphics, solids modeling; introduction to computer-aided*

manufacturing. Prerequisite: AME 204 or CE 225; recommended preparation: AME 308.

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 415 Turbine Design and Analysis (3, Fa) *Physics of turbine operation; design and analysis for the development of turbine hardware for propulsion and power generation.* Recommended preparation: familiarity with Matlab.

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, Sp) *(Enroll in EE 423L)*

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

AME 430 Thermal Systems Design (3, Fa) *Design methodology for thermal systems; boilers, condensers, air conditioning, power generation, air pollution control, combustion and alternative fuels.* Prerequisite: AME 331; recommended preparation: AME 312.

AME 436 Energy and Propulsion (3, Fa) *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, FaSp) *Individual engineering projects designed and constructed to model and test a physical principle or system.* Prerequisite: AME 341bL.

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, FaSp) *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 Subsurface Methods (3) *(Enroll in PTE 465L)*

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 (1-8, max 12)
Individual research and readings. Not available for graduate credit.

AME 491 Undergraduate Design Projects II (1, max 4, FaSp) 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, FaSpx)
Course content to be selected each semester from recent developments in mechanical engineering and related fields.

AME 502 Modern Topics in Aerospace Design (3, Fa) *Current topics in Aerospace Engineering are addressed by a number of industry panelists. Students, under panelists' supervision and guidance, complete independent research reports and briefings. Recommended preparation:* AME 261, AME 441, AME 481 or equivalents. Genuine interest in design of flight vehicles. Open only to senior, master, and doctoral students.

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

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, Sp) *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 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, Fa)
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, Sp) *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, Sp) *Review of analytical methods in heat conduction; moving boundaries melting and freezing; sources and sinks, anisotropic and composite media; numerical methods for steady and unsteady problems. Recommended preparation:* AME 331, AME 526.

AME 516 Convection Processes (3, Sp) *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 526; *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 520 Modeling of Bio-Systems (3, Sp)
Interacting population dynamics, Cheyne-Stokes respiration, reaction kinetics, biological switches, neuronal models, BZ reaction, phase locking, reaction diffusion, chemotaxis, biological waves, and animal coat patterns. Recommended preparation: MATH 245.

AME 521 Engineering Vibrations II (3, Fa) *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, Fa) Lagrange equations; nonlinear maps and differential equations; fixed points; periodic motion; qualitative/quantitative and local/global analysis; higher order systems; stability; bifurcations; chaos; fractals.

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, FaSpSm)
Typical engineering problems discussed on a physical basis. Vector analysis; functions of complex variables, infinite series, residues.

AME 526 Engineering Analytical Methods (3, FaSpSm) 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 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, FaSp) *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 534 Nuclear Thermal-Hydraulics (3, Fa)
Thermal-fluid phenomena for nuclear power stations. Heat generation by nuclear reactions, conduction in fuel rods, and transport of generated heat by convection, boiling, and condensation. Open only to master's and doctoral students. Prerequisite: AME 457 or AME 530a; *and AME 526 and AME 581; recommended preparation:* undergraduate degree in engineering.

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; non-linear advection problems. Recommended preparation:* AME 526. *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, electroosmotic 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, Sp)
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 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, Irregular) *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, FaSm) (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, Fa) 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, Sp) 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 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 573 Aerosol Physics and Chemistry (3, Sp) Examination of the fundamentals of aerosol formation and evolution, aerosol effects on health and climate, and the principles of aerosol measurement. Open only to master's and doctoral students.

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: AME 525 or AME 526 or CE 525 or CE 526.*

AME 577 Survey of Energy and Power for a Sustainable Future (3, FaSp) Power production includes conventional fossil fuels, synthetic fuels, hydroelectric, solar, wind, geothermal, biomass and nuclear. The environmental consequences of various energy sources are discussed. (Duplicates credit in CHE 510.)

AME 578 Modern Alternative Energy Conversion Devices (3, FaSp) Alternative energy/power conversion including fuel cells, photovoltaic, batteries, and biologically inspired energy processes; biomass conversion and utilization; Environmental implications of alternative energy processes.

AME 579 Combustion Chemistry and Physics (3, Sp) 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 582 Nuclear Reactor Physics (3, Sp) *Neutron-induced fission chain reactions, reactor criticality. Neutron transport and diffusion in nuclear reactors. Mathematical/computational foundation for diffusion theory and transport calculations for fission reactor design/analysis. Open only to master's and doctoral students. Prerequisite: AME 526 and AME 581; recommended preparation: undergraduate degree in engineering and PHYS 153L.*

AME 583 Effects of Radiation on Health (3, Sp) *Nuclear physics relevant to human health. Biological effects of radiation, quantification and measurement of different types of radiation affecting living tissue, radiation protection, nuclear accidents. Open only to master's and doctoral students. Prerequisite: AME 526 and AME 581; recommended preparation: undergraduate degree in engineering and 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 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, FaSp) 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 647 Multiscale Methods in Mechanics (3) (Enroll in CE 647)

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.

Astronautical Engineering

Robert Glenn Rapp Engineering Research Building (RRB)
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Chair: Daniel A. Erwin, Ph.D.*

Faculty

Professors: Daniel A. Erwin, Ph.D. (Aerospace Engineering); Mike Gruntman, Ph.D. (Aerospace Engineering, Systems Architecting and Engineering); Darrell L. Judge, Ph.D. (Physics and Astronomy); Joseph A. Kunc, Ph.D. (Physics and Astronomy, Aerospace Engineering, Systems Architecting and Engineering); F. Stan Settles, Ph.D. (Industrial and Systems Engineering, Systems Architecting and Engineering)*

Associate Professor: Joseph Wang, Ph.D.

Professors of Engineering Practice: George Friedman, Ph.D. (Systems Architecting and Engineering); Azad Madni, PhD. (Systems Architecting and Engineering)

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

Adjunct Professor: William Tobiska, Ph.D.

Adjunct Associate Professor: Michael Kezirian, Ph.D.

Research Professors: Herbert Schorr, Ph.D. (Computer Science), Vice Dean for Engineering, Executive Director Emeritus, Information Sciences Institute; Elliot Axelband, Ph.D.

Research Associate Professor: Sergey Gimelshein, Ph.D.

Research Assistant Professor: Jo Ann Lane, Ph.D.

*Recipient of university-wide or school teaching award.

Aerospace Engineering Honor Society: Sigma Gamma Tau

Degree Requirements

Undergraduate Program Educational Objectives

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

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

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

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

- Graduates will communicate with skill as members and leaders of multidisciplinary teams.

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

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

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Astronautical Engineering prepares graduates to have a knowledge of orbital mechanics, space environment, attitude determination and control, telecommunications, space structures and rocket propulsion. The program also prepares graduates to have design competence that includes integration of astronautical topics.

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.

The requirement for this degree is 128 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied toward the major, regardless of the department in which the courses are taken. See also the common requirements for undergraduate degrees section.

composition/writing requirements		Units
WRIT 130	Analytical Writing	4
WRIT 340	Advanced Writing	4
		8

General Education		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	Foundations of Astronautical Engineering	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 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
ASTE 301ab	Thermal and Statistical Systems	3-3
ASTE 330	Introduction to Spacecraft Systems and the Space Environment	3
ASTE 421x	Space Mission Design	3
ASTE 470	Spacecraft Propulsion	3
ASTE 480	Spacecraft Dynamics	3
Elective	Technical elective**	12
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 46 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, MATH 226 and MATH 245; PHYS 151L, PHYS 152L and PHYS 153L.

Required courses		units
ASTE 280	Foundations of Astronautical Engineering	3
ASTE 301a	Thermal and Statistical Systems I	3

ASTE 330	Introduction to Spacecraft Systems and the Space Environment	3
ASTE 421x	Space Mission 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 557	Spacecraft Structural Strength and Materials	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 adviser. 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, ASTE faculty suggest the following areas of concentration:

Spacecraft propulsion		units
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		units
Choose two core electives from:		
ASTE 556	Spacecraft Structural Dynamics	3
ASTE 557	Spacecraft Structural Strength and Materials	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		units
Choose two core electives from:		
ASTE 523	Design of Low Cost Space Missions	3
ASTE 527	Space Studio Architecting	3
ASTE 557	Spacecraft Structural Strength and Materials	3

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

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

Engineer in Astronautical Engineering

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

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. 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 Department of Astronautical Engineering, can be obtained from the ASTE student adviser 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 554	Spacecraft Sensors	3
ASTE 556	Spacecraft Structural Dynamics	3
ASTE 557	Spacecraft Structural Strength and Materials	3
ASTE 570	Liquid Rocket Propulsion	3
ASTE 572	Advanced Spacecraft Propulsion	3
ASTE 580	Orbital Mechanics I	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
ASTE 599	Special Topics	3

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

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

Courses of Instruction

Astronautics and space technology (ASTE)

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

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 Foundations of Astronautical Engineering (3, Sp) *Coordinate systems and transformations. Spherical trigonometry. Orientation angles. Spacecraft orbits and orbital maneuvers. Introduction to rocket propulsion, spacecraft attitude dynamics and control, and space environment. Prerequisite: MATH 226 and PHYS 152L. Recommended preparation: Skill in MATLAB programming.*

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 Introduction to Spacecraft Systems and the Space Environment (3, Fa) *Spacecraft systems: attitude determination and control, power, thermal, command and data handling, telecommunication, structures and mechanisms, propulsion. Space environment: atmosphere, gravity gradients, radiation. Prerequisite: ASTE 280 and PHYS 153.*

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

ASTE 421x Space Mission Design (3, Sp) *Space systems engineering process: requirements definition; trade studies; system integration; technical reviews; cost and schedule development; case studies; ethics. Capstone design experience. Open only to seniors. Not for graduate credit. Prerequisite: ASTE 330.*

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. 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. Prerequisite: senior standing.*

ASTE 490x Directed Research (1-8, max 12, 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. 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.

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. 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. Recommended preparation: ASTE 520 or experience in space industry.*

ASTE 529 Safety of Space Systems and Space Missions (3) *Engineering methodology and analysis techniques for safety certification and mission assurance of robotic and human space systems and space missions by government and commercial industry. Recommended preparation: ASTE 520 or some experience in space engineering. Open only to Engineering graduate students.*

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.*

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. 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. 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 557 Spacecraft Structural Strength and Materials (3) Spacecraft structural strength analysis and design concepts overview; spacecraft material selection; analysis of composite materials; finite element method; spacecraft configuration; structural testing; bolted joint design. Open only to master's, professional, and doctoral students.

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. 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.

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

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. 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. /p>

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 683 Advanced Spacecraft Navigation (3) *Advanced topics in spacecraft navigation: rendezvous, frozen/sun synchronous orbits, stationkeeping. Nonlinear filtering for orbit and attitude determination. Optical navigation. Mission applications. Prerequisite: ASTE 580 and ASTE 583; recommended preparation:* skill in MATLAB programming.

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

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 (2-2-2-2-0, FaSpSm) Credit on acceptance of dissertation. Graded IP/CR/NC.

Biomedical Engineering

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Chair: Norberto M. Grzywacz, Ph.D.

Faculty

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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. (Opthalmology)

Provost Professor of Biological Sciences, Biomedical Engineering, Physiology and Biophysics, Stem Cell Biology and Regenerative Medicine, Pediatrics, Radiology and Ophthalmology: Scott Fraser, Ph.D. (Biological Sciences)

Dean's Professor in Biomedical Engineering: Kirk Shung, Ph.D.

Provost Associate Professor of Biomedical Engineering, Neurology, Biokinesiology, and Physical Therapy: Terence D. Sanger, M.D., Ph.D.

WISE Jr. Gabilan Assistant Professor of Biomedical Engineering: Stacey D. Finley, Ph.D.

WISE Jr. Gabilan Assistant Professor of Biomedical Engineering: Megan McCain, Ph.D.

Professors: Michael O. Arbib, Ph.D. (Computer Science, Neurobiology); Theodore W. Berger, Ph.D. (Neurobiology); Roberta D. Brinton, Ph.D. (Molecular Pharmacology and Toxicology); Peter S. Conti, M.D., Ph.D. (Radiology); David Z. D'Argenio, Ph.D.; Scott Fraser, Ph.D. (Biological Sciences); Norberto M. Grzywacz, Ph.D. (Electrical Engineering); 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); Jay Lieberman, Ph.D. (Orthopaedic Surgery); Gerald E. Loeb, M.D.; Anupam Madhukar, Ph.D. (Chemical Engineering and Materials Science, Physics); Vasilis Z. Marmarelis, Ph.D. (Electrical Engineering); Jill McNitt-Gray, Ph.D. (Biological Science); Ellis Meng, Ph.D. (Electrical Engineering); Chrysostomos Nikias, Ph.D. (Electrical Engineering); Dennis P. O'Leary, Ph.D. (Otolaryngology, Physiology and Biophysics); K. Kirk Shung, Ph.D.; Prakash Shrivastava, Ph.D. (Radiation Oncology); Armand R. Tanguay Jr., Ph.D. (Electrical Engineering, Materials Science); Francisco Valero-Cuevas, Ph.D. (Biokinesiology); Stanley M. Yamashiro, Ph.D. (Electrical Engineering)*

Associate Professors: Robert H.-P. Chou, M.D., Ph.D. (Physiology and Biophysics); Daniel P. Holschneider, M.D. (Psychiatry); Hossein Jadvar, M.D., Ph.D. (Radiology); Shuliang Jiao, Ph.D. (Ophthalmology); Zhong-Lin Lu, Ph.D. (Psychology); Bartlett W. Mel, Ph.D.; Krishna Nayak, Ph.D. (Electrical Engineering); Alapakkam P. Sampath, Ph.D. (Physiology and Biophysics); Terence D. Sanger, M.D., Ph.D. (Neurology, Biokinesiology); Stefan Schaal, Ph.D. (Computer Science); Nicolas Schweighofer, Ph.D. (Biokinesiology); Pin Wang, Ph.D., (Chemical Engineering and Materials Science); James D. Weiland, Ph.D. (Ophthalmology); Jesse T. Yen, Ph.D.

Assistant Professors: Andrea Armani, Ph.D. (Chemical Engineering and Materials Science); Greg D. Field, Ph.D. (Cell and Neurobiology); Stacey D. Finley, Ph.D.; Radha Kalluri, Ph.D. (Otolaryngology); Jason Kutch, Ph.D. (Biokinesiology); Noah Malmstadt, Ph.D. (Chemical Engineering and Materials Science); J. Andrew MacKay, Ph.D. (Pharmacology and Pharmaceutical Sciences); Meghan McCain, 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); Donald J. Marsh, M.D.; Robert V. Shannon, Ph.D. (House Ear Institute); Qifa Zhou, Ph.D.

Research Associate Professors: Qian-Jie Fu, Ph.D. (House Ear Institute); John J. Granacki, Ph.D. (Electrical Engineering-Systems/ISI); Eun Jin Lee, Ph.D.; Dong Song, Ph.D.

Research Assistant Professors: Jean-Marie Bouteiller, Ph.D.; Rahman Davoodi, Ph.D.; Alireza Dibazar, Ph.D.; Arkadivsz Gertych, Ph.D. (Cedars-Sinai Medical Center); Hyung Ham (David) Kim, Ph.D.; Clara Lajonchere, Ph.D.; Rongsong Li, Ph.D.

Associate Professors of Research: Stefan Bluml, Ph.D. (Radiology); Brent J. Liu, Ph.D. (Radiology); Tishya A.L. Wren, M.D., Ph.D. (Orthopaedics/Pediatrics Children's Hospital and Radiology)

Assistant Professors of Research: Stephan G. Erberich, Ph.D. (Radiology); Tracy C. Grikscheit, M.D. (Surgery and Children's Hospital); Bo Han, Ph.D. (Surgery); Natasha Leporé, Ph.D. (Radiology and Children's Hospital); 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, Children's Hospital)

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

Adjunct Associate Professors: Samuel Landsberger, Sc.D. (Rancho Los Amigos); Shirin Towfigh, M.D. (Cedars Sinai)

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); H. K. Huang, D.Sc. (Radiology)

*Recipient of university-wide or school teaching award.

Degree Requirements

Undergraduate Program Educational Objectives

Graduates of the undergraduate program in Biomedical Engineering are expected to attain the following objectives within a few years after graduation:

- 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.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Biomedical Engineering provides both breadth and depth across the range of engineering topics implied by the title. The program prepares graduates to have an understanding of biology and physiology; and the capability to apply advanced mathematics (including differential equations and statistics), science and engineering to solve the problems at the interface of engineering and biology. The curriculum prepares graduates with the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems.

Bachelor of Science in Biomedical Engineering

The Department of Biomedical Engineering offers a Bachelor of Science degree in Biomedical Engineering. Additionally, there are three possible areas of emphasis within this biomedical engineering program major. These are biochemical engineering, electrical engineering, and mechanical engineering. An area of emphasis appears in parenthesis after the primary major name on the transcript. The requirement for the degree is 128 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied toward the major, regardless of the department in which the courses are taken.

See common requirements for undergraduate degrees.

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

composition/writing requirement		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**units**

ment

Column 1

Pre-major requirements	General education* +	20
		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 423	Statistical Methods in Biomedical Engineering	3
BME 425	Basics of Biomedical Imaging	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

Electrical Engineering

EE 150L	Engineering Computational Methods	3
EE 202L	Linear Circuits	4
EE 301L	Linear Systems	4

Major Electives — units

Technical electives	9
Total units:	128

* WRIT 150 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 Emphasis in Biochemical Engineering

The requirement for the degree with an emphasis in biochemical engineering is 132 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied towards the major, regardless of the department in which the courses are taken. See General Education **and additional** common requirements for undergraduate degrees.

composition/writing requirement		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4

Column 2

WRIT 340	Advanced Writing	3
General Education		**Units**
General education* +		20
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

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 202L	Linear Circuits	4

Materials Science

MASC 310	Materials Behavior and Processing	3

Major electives — units

Technical elective	2
Total units:	132

* GE Category VI is taken concurrently with WRIT 150.

** 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.

Column 3

Bachelor of Science in Biomedical Engineering Emphasis in Electrical Engineering

The requirement for the degree with an emphasis in electrical engineering is 133 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied towards the major, regardless of the department in which the courses are taken. See common requirements for undergraduate degrees.

composition/writing requirement		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**Units**
General education* +		20
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
MATH 445	Mathematics of Physics and Engineering II	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	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 423	Statistical Methods in Biomedical Engineering	3
BME 425	Basics of Biomedical Imaging	3

Biology

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

Chemistry

CHEM 322aL	Organic Chemistry	4

Electrical Engineering

EE 101	Introduction to Digital Logic	3
EE 150L	Engineering Computational Methods	3
EE 254L	Introduction to Digital Circuits	4
EE 202L	Linear Circuits	4
EE 301L	Linear Systems	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 150 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 Emphasis in Mechanical Engineering

The requirement for the degree with an emphasis in mechanical engineering is 132 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied towards the major, regardless of the department in which the courses are taken. See common requirements for undergraduate degrees.

composition/writing requirement		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**units**
General education* +		20
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 Requirements		
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	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
Major requirements		**units**
Aerospace and Mechanical Engineering		
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
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 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
Electric Engineering		
EE 150L	Engineering Computational Methods	3
EE 202L	Linear Circuits	4
Materials Science		
MASC 310	Materials Behavior and Processing	3

Major Electives	units
Technical electives	6
Total units:	132

* WRIT 150 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 Ostrow School of Dentistry of USC.

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		Units
BME 501	Advanced Topics in Biomedical Systems	4
BME 502	Advanced Studies of the Nervous System	4
BME 511	Physiological Control Systems	3
BME 513*	Signal and Systems Analysis	3
BME 533	Seminar in Bioengineering	1
BME 594abz	Master's Thesis (2-2-0), or Technical Elective (4)	4
Electives	Technical	9
		28

*Students who have taken an advanced undergraduate or master's level course in system and signal analysis may substitute BME 523 for BME 513 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		Units
BME 501	Advanced Topics in Biomedical Systems	4
BME 513	Signal and Systems Analysis	3
BME 525	Advanced Biomedical Imaging	3
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	7
		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		Units
BME 501	Advanced Topics in Biomedical Systems, or	
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	
BME 416	Development and Regulation of Medical Products	3
MPTX 515	Quality Systems and Standards, or	
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
		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 adviser for approval.

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 adviser 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.

Qualifying Exam Committee

During the third semester, the student must make a tentative major field selection as described above and form a qualifying exam 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 Health, Technology and Engineering (HTE@USC)

Academic Director: Terry Sanger, M.D., Ph.D., Provost Associate Professor of Biomedical Engineering, Neurology, Biokinesiology, and Physical Therapy

Administrative Director: George Tolomiczenko, Ph.D., Assistant Professor, Neurology

This program offers current second-year USC Ph.D. engineering students and first-year M.D. students an opportunity to learn about and gain experience in medical device and process innovation. Through project-based and interdisciplinary collaboration, students will augment their current programs with a set of courses and lab experiences linking medical and engineering research groups. By applying design-informed approaches toward problem identification and solution prototyping, students will be involved in all the steps of medical device or process innovation from conception to commercialization. The program aims to create interdisciplinary, boundary-spanning, inventive entrepreneurs seeking early practical experience with device and method innovation in health care. Program participants will form bonds with a group of like-minded medical students and engineers who will be their mentors, colleagues and contacts as they advance in their careers.

The courses unique to the program include a seminar sequence (Topics in Health, Technology and Engineering), which must be taken during the first two years of involvement with the HTE@USC program, a case studies sequence taken during the second year and a research course to earn project-related credits:

courses		Units
BME 566abcd	Topics in Health, Technology and Engineering:	2-2-2-2
BME 567ab	Case Studies in Health, Technology and Engineering	1-1
790	Research (in the student's major department)	2-8

Other required courses that are part of the M.D. curriculum (Ph.D. students enroll in INTD course versions of the same courses open only to HTE students on CR/NC basis):

INTD 621ab	Introduction to Clinical Medicine (ICM) for HTE	3-3
INTD 622L	Pre-clinical System Block for Health, Technology and Engineering	3-5

Candidates interested in applying should contact HTE@USC via email at hte@usc.edu.

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, biopotential measurements, static and dynamic calibration of physiological transducers. Prerequisite: EE 202L.*

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 202L.*

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 202L.*

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) *Engineering, clinical applications and modern physics concepts underlying X-ray imaging, Computed Tomography (CT), nuclear medicine, positron emission tomography, Magnetic Resonance Imaging (MRI), ultrasound imaging. Prerequisite: PHYS 152L.*

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

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 453 Engineering Biomedical Innovations (3, Sp) *Engineering principles in design, modeling, and analysis of biomedical innovations will be presented to develop creative solutions for real-world medical problems or treatment implementation. Corequisite: BME 405L; recommended preparation:* BME 416.

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

BME 490x Directed Research (1-8, max 12) 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 504 Neuromuscular Systems (3, Fa) *Introduces the fundamentals of mathematical, Newtonian, and robotic analysis applicable to multi-muscle biomechanical systems. Combines physiology with numerical simulations to understand and predict motor function. Recommended Preparation:* Matlab programming, fundamentals of mechanics, linear algebra.

BME 505abL Laboratory Projects in Biomedical Engineering (4, FaSpSm) Integration of biomedical science, engineering principles and state-of-the-art technology for the study of selected physiological systems in the laboratory setting. Laboratory. Graded CR/NC.

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 520 Modeling of Bio-Systems (3, Sp) (Enroll in AME 520)

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 (3, Sp) *Advanced scientific and engineering principles of biomedical imaging including magnetic resonance, X-ray computed tomography, ultrasound, and single photon and positron emission tomography. Open only to master's and doctoral students. Prerequisite:* BME 513 or EE 483.

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 566abcd Topics in Health, Technology and Engineering (a: 2, Fa; b: 2, Sp; c: 2, Fa; d: 2, Sp) *Interdisciplinary approach to impart the skills, knowledge and familiarity with stages of collaborative projects related to medical device and methods innovation in health care settings. Open only to health, technology and engineering majors. c: Concurrent enrollment: BME 567a. d: Concurrent enrollment: BME 567b.*

BME 567ab Case Studies in Health, Technology and Engineering (a: 1, Fa; b: 1, Sp) *Learning from cases illustrating paths from health care problems to solutions. Faculty, students and invited guests will provide examples of both successful and unsuccessful innovation attempts. Open only to health, technology and engineering students. a: Concurrent enrollment: BME 566c. b: Concurrent enrollment: BME 566d.*

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

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 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: Richard Roberts, Ph.D.

Faculty

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

Dean's Chair in Chemical Engineering and Materials Science: Priya Vashishta, Ph.D. (Computer Science, Physics)

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

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., P.E.

Jack Munushian Early Career Chair: Malancha Gupta, Ph.D.

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

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

Fluor Professor in Process Engineering: S. Joe Qin, Ph.D. (Electrical Engineering and Industrial and Systems Engineering)

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

Judge Widney Professor of Chemical Engineering and Chemistry: Ray R. Irani; Ph.D. (Chemistry)

Zohrab A. Kaprielian Fellow in Engineering: Pin Wang, Ph.D.

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, Earth Sciences); Aiichiro Nakano, Ph.D. (Computer Science, Physics, 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); Pin Wang, Ph.D.; Chongwu Zhou, Ph.D. (Electrical Engineering)

Associate Professors: Andrea M. Armani, Ph.D. (Electrical Engineering, Chemistry and Biomedical Engineering); Edward Goo, Ph.D.; Behnam Jafarpour, Ph.D.; Kristian Jessen, Ph.D.; C. Ted Lee Jr., Ph.D.; Grace Lu, Ph.D. (Physics and Electrical Engineering);*Noah Malmstadt, Ph.D.; Katherine S. Shing, Ph.D.**

Assistant Professors: Andrea M. Armani, Ph.D. (Electrical Engineering, Chemistry, Biomedical Engineering); Malancha Gupta, Ph.D.; Andrea Maria Hodge, Ph.D. (Aerospace and Mechanical Engineering); Jongseung Yoon, Ph.D.

Research Professors: Fred Aminzadeh, Ph.D.; Don Zhang, Ph.D. (Civil and Environmental)

Emeritus Professors: Elmer L. Dougherty, Ph.D.; Murray Gershenzon, Ph.D. (Electrical Engineering); Florian Mansfeld, Ph.D.; Ronald Salovey, Ph.D.; Peter Will, Ph.D. (Astronautical Engineering, Industrial and Systems Engineering)*

*Recipient of university-wide or school teaching award.

Chemical Engineering Honor Society: Omega Chi Epsilon

Degree Requirements

Undergraduate Program Educational 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, biochemical, 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 undergraduate program in Chemical Engineering are expected to attain the following objectives within a few years after graduation:

- To obtain employment and succeed 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.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Chemical Engineering provides a thorough grounding in the basic sciences including chemistry, physics and/or biology, with some content at an advanced level, as appropriate to the objectives of the program. The curriculum includes the engineering application of these basic sciences to the design, analysis and control of chemical, physical and/or biological processes, including the hazards associated with these processes.

Bachelor of Science in Chemical Engineering Degree

The Mork Family Department of Chemical Engineering offers a Bachelor of Science degree in Chemical Engineering. Additionally, there are five possible areas of emphasis within this chemical engineering program major. These are: biochemical engineering (133 units); environmental engineering (132 units); nanotechnology (128 units); petroleum engineering (133 units); and polymer/materials science (133 units). An area of emphasis appears in parentheses after the primary major name on the transcript.

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

Common Requirements for the B.S. Degree and All Areas of Emphasis (108 units)

See also common requirements for undergraduate degrees.

composition/WRITING COURSES		units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education**		**units**
General education+		20
CHEMISTRY COURSES		**units**
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4

CHEM 300L	Analytical Chemistry	4
CHEM 322aL	Organic Chemistry	4
CHEM 430a	Physical Chemistry	4
MATH COURSES		**units**
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
PHYSICS COURSES		**units**
PHYS 151***	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152	Fundamentals of Physics II: Electricity and Magnetism	4
CHEMICAL ENGINEERING COURSES		**units**
CHE 120	Introduction to Chemical Engineering	3
CHE 205	Numerical Methods in 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
CHE 485	Computer-Aided Chemical Process Design	3

* GE Category VI is taken concurrently with WRIT 150.

** 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.

Additional Requirements for Individual Degrees

Bachelor of Science in Chemical Engineering

The requirement for the degree in the absence of an area of emphasis is 129 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied toward the major, regardless of the department in which the courses are taken. In addition to the previously listed common requirements, students must also take the following courses:

CHEMISTRY TECHNICAL ELECTIVE		units
CHEM 322bL	Organic Chemistry, or	
CHEM 430b	Physical Chemistry	4
CHEMICAL ENGINEERING COURSES		**units**
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 476	Chemical Engineering Materials	3
CHE Technical Elective		
An upper division CHE course		3
additional electives (8-9 units)		**units**
Suggested Courses		
CE 205	Statics	2
EE 438L	Processing for Microelectronics	3
ISE 460	Engineering Economy, or	
BUAD	Technical Entrepreneurship	3

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Bachelor of Science in Chemical Engineering Emphasis in Biochemical Engineering

The requirement for the degree with an emphasis in biochemical engineering is 133 units.* A scholarship average of C (2.0) or higher is required for 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
BIO-ELECTIVES		units
BISC 403	Advanced Molecular Biology, or	
	approved bio-engineering elective**	3-4
BME 410	Introduction to Biomaterials and Tissue Engineering	3
CHE 489	Biochemical Engineering	3
Engineering Elective		units
CHE 405	Applications of Probability and Statistics for Chemical Engineers, or	
ISE 460	Engineering Economy	3

Students in the biochemical engineering option must take a minimum of 48 engineering units total to graduate.

*** Student may combine a 3-unit approved bio-engineering elective with 1 unit of free elective.*

Bachelor of Science in Chemical Engineering Emphasis in Environmental Engineering

The requirement for the degree with an emphasis in environmental engineering is 132 units. A cumulative grade point average of C (2.0) is required for all upper division courses applied toward the major, regardless of the department in which the courses are taken. 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 486	Design of Environmentally Benign Process Plants	3
OTHER COURSES		units
CE 453	Water Quality Control	3
CE 463L	Water Chemistry and Analysis	3
ISE 460	Engineering Economy, or	
BUAD 301	Technical Entrepreneurship	3
PTE 463L	Introduction to Transport Processes in Porous Media	3
Air Pollution Elective		
ENE 428	Air Pollution Fundamentals, or	
ENE 429	Air Pollution Control	3

Bachelor of Science in Chemical Engineering Emphasis in Nanotechnology

The requirement for the degree with an emphasis in nanotechnology is 128 units. A cumulative grade point average of C (2.0) is required for all upper division courses applied toward the major, regardless of the department in which the courses are taken. In addition to the previously listed common requirements, students must also take the following courses:

Chemistry		units
CHEM 453	Advanced Inorganic Chemistry	4
Chemical Engineering and Materials Science (11 Units)		units
CHE 487	Nanotechnology and Nanoscale Engineering through Chemical Processes	3
CHE 391L	Introduction to Nanotechnology Research (2) and	
CHE 491	Nanotechnology Research for Undergraduates (2) or approved upper division undergraduate electives (4)	4
MASC 350L	Nanostructured Materials: Design, Synthesis, and Processing	4
Nanotechnology electives		units
EE 438L	Processing for Microelectronics, or	
CHE 489	Biochemical Engineering, or	
PTE 463L	Introduction to Transport Processes in Porous Media	3
Other electives		units
CHE 405	Applications of Probability and Statistics for Chemical Engineers, or	
ISE 460	Engineering Economy, or	
BUAD 301	Technical Entrepreneurship	3

Bachelor of Science in Chemical Engineering Emphasis in Petroleum Engineering

The requirement for the degree with an emphasis in petroleum engineering is 133 units. A cumulative grade point average of C (2.0) is required for all upper division courses applied toward the major, regardless of the department in which the courses are taken. In addition to the previously listed common requirements, students must also take the following courses:

CHEMISTRY COURSE		units
Chemistry Technical Elective		
CHEM 322bL	Organic Chemistry, or	
CHEM 430b	Physical Chemistry	4
CHEMICAL ENGINEERING COURSES		units
CHE 405	Applications of Probability and Statistics for Chemical Engineers	3
CHE 476	Chemical Engineering Materials	3
PETROLEUM 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
other COURSE		units
ISE 460	Engineering Economy, or	
BUAD 301	Technical Entrepreneurship	3

Bachelor of Science in Chemical Engineering Emphasis in Polymer/Materials Science

The requirement for the degree with an emphasis in polymer/materials science is 133 units. A cumulative grade point average of C (2.0) is required for all upper division courses applied toward the major, regardless of the department in which the courses are taken. 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 472	Polymer Science and Engineering	3
CHE 476	Chemical Engineering Materials, or	
MASC 310	Materials Behavior and Processing	3
MASC 350L	Nanostructured Materials: Design, Synthesis, and Processing	3
Polymer/Materials Electives (choose three courses)		UNITS
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
OTHER COURSE		units
CHE 405	Applications of Probability and Statistics for Chemical Engineers, or	
ISE 460	Engineering Economy, or	
BUAD 301	Technical Entrepreneurship	3

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. Only available to graduate students currently enrolled.

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 advisers.

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

Courses of Instruction

Chemical Engineering (CHE)

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

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 205 Numerical Methods in Chemical Engineering (3, Sp) *Computational tools for solving numerical problems in Chemical Engineering. Prerequisite: MATH 125.*

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 391L Introduction to Nanotechnology Research (2) Planning and execution of an experiment, and presentation of findings through oral presentations and a written report. Application of the scientific method learned through immersion in a lab environment. Graded CR/NC.

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

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 488 Molecular and Cellular Bioengineering (3, Fa) *Design, synthesis, and analysis of biological molecules; routes to understand and engineer living systems at the molecular and cellular level; systems and synthetic biology. Prerequisite: BISC 320.*

CHE 489 Biochemical Engineering (3, Sp) *Application of chemical engineering principles to biological and biochemical processes and materials. Design of biochemical reactors or of processes for separation and purification of biological products. Prerequisite: CHE 330, BISC 320L.*

CHE 490x Directed Research (1-8, max 12) Individual research and readings. Not available for graduate credit.

CHE 491 Nanotechnology Research for Undergraduates (2, max 4) *Independent research in nanotechnology. Research project selected by the student in close consultation with a research adviser. Open only to juniors and seniors. Prerequisite: CHE 391L.*

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 master and doctoral students. (Duplicates credit in AME 577.)

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, max 8, FaSpSm) 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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Faculty

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

Professors: P. Daniel Dapkus, Ph.D. (Electrical Engineering); Martin Gundersen, Ph.D. (Electrical Engineering); Rajiv K. Kalia, Ph.D. (Physics, Computer Science); Michael E. Kassner, Ph.D. (Aerospace and Mechanical Engineering); Terence G. Langdon, Ph.D., D.Sc. (Aerospace and Mechanical Engineering, Earth Sciences); Anupam Madhukar, Ph.D. (Physics); Aiichiro Nakano, Ph.D. (Computer Science, Physics, Biomedical Engineering); Steven R. Nutt, Ph.D. (Aerospace and Mechanical Engineering); Charles G. Sammis, Ph.D. (Earth Sciences)*; Armand R. Tanguay Jr., Ph.D. (Electrical Engineering, Biomedical Engineering); Mark E. Thompson, Ph.D. (Chemistry); Priya Vashishta, Ph.D. (Physics, Computer Science); Chongwu Zhou, Ph.D. (Chemistry, Electrical Engineering)

Associate Professors: Andrea Armani, Ph.D. (Electrical Engineering, Chemistry, Biomedical Engineering); Edward Goo, Ph.D..; Grace Lu, Ph.D. (Physics and Electrical Engineering)

Assistant Professors: Andrea Hodge, Ph.D. (Aerospace and Mechanical Engineering); Jongseung Yoon, Ph.D.

Emeritus Professors: Murray Gershenzon, Ph.D. (Electrical Engineering); Florian Mansfeld, Ph.D.; Ronald Salovey, Ph.D. (Chemical 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
Adviser 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 350L 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, microfabrication and smart materials. Prerequisite: CHEM 105a or CHEM 115a or MASC 110L, PHYS 152.*

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

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, electroxidation, 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 570 Introduction to Photovoltaic Solar Energy Conversion (3) Introduction to the physical principles, implementation materials, devices, and manufacturing costs of solar cells and panels for photovoltaic conversion of solar radiation to electricity.

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 Advanced Semiconductor Device Physics (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: Steven R. Nutt, 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.

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

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

Associate Professors: Behnam Jafarpour, Ph.D.; Kristian Jessen, Ph.D.

Adjunct Associate Professors: Stephen Cheung, Ph.D.; Robert Ehrlich, Ph.D.; Donald G. Hill, Ph.D.; Victor M. Ziegler, Ph.D.

Adjunct Assistant Professors: Andrei Popa, Ph.D.; Ehsan Tajer, Ph.D.

Lecturers: Jincai, Chang, Ph.D.; George Chilingar, Ph.D.; Donald Gautier, Ph.D.; Martin Karrenbach, Ph.D.; Keith Millheim, Ph.D.; Bradford Pierce, M.S.; Wenlong Xu, Ph.D.; Ke-Thia Yao, Ph.D.

Research Professors: Fred Aminzadeh, Ph.D.; Dongxiao Zhang, Ph.D.

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

Petroleum Engineering Honor Society: Pi Epsilon Tau

Degree Requirements

Bachelor of Science in Chemical Engineering

Emphasis in Petroleum Engineering

See the listing under Chemical Engineering.

Bachelor of Science in Mechanical Engineering

Emphasis in Petroleum Engineering

See the listing under Aerospace and Mechanical Engineering.

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. Electives vary according to the area of interest. A student may be permitted to elect the program without thesis upon approval from the department.

Master of Science in Petroleum Engineering (Geoscience Technologies)

The Master of Science in Petroleum Engineering (Geoscience Technologies) is a unique degree that emphasizes recent developments in the field of unconventional oil and gas resources and modern techniques for mapping and monitoring of subterranean resources. The program may be completed via the USC Viterbi School's Distance Education Network (DEN). All courses for the degree must be taken at USC.

Students without a B.S. in Petroleum Engineering will normally be required to complete prerequisite courses before beginning the M.S. program. Specific prerequisite courses are decided upon consultation with the department adviser. Units from these courses cannot be applied toward the degree.

A minimum of 34 units is required to earn the M.S. in Petroleum Engineering (Geoscience Technologies).

Core required courses (18 units)		units
PTE 507	Engineering and Economic Evaluation of Subsurface Reservoirs	3
PTE 508	Numerical Simulation of Subsurface Flow and Transport Processes	3
PTE 517	Testing of Wells and Aquifers	3
PTE 531	Enhanced Oil Recovery	3
PTE 555	Well Completion, Stimulation, and Damage Control	3
PTE 582	Fluid Flow and Transport Processes in Porous Media	3
Take 4 out of 5 courses shown below (12 units)		**units**
PTE 502	Advanced Reservoir Characterization	3
PTE 503	Technology of Unconventional Oil and Gas Resources Development	3
PTE 504	Geophysics for Petroleum Engineers	3
PTE 505	Inverse Modeling for Dynamic Data Integration	3
PTE 572	Geostatistics	3
Elective from a group of approved PTE courses:		4

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.

Students without a B.S. in Petroleum Engineering will normally be required to complete prerequisite courses before beginning the M.S. program. Specific prerequisite courses are decided upon consultation with the department adviser. Units from these courses cannot be applied toward the degree.

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. Students without a B.S. in Petroleum Engineering will normally be required to complete prerequisite courses before beginning the certificate program. Specific prerequisite courses are decided upon consultation with the department adviser. Units from these courses cannot be applied toward the certificate.

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@Viterbi). 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; capillary 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 (1-8, max 12) 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 500 Computational Reservoir Modeling (3, Fa) *Introduction to mathematical and computational methods in characterizing, modeling, and describing the subsurface flow and transport phenomena. Recommended preparation:* Familiarity with basic calculus, differential equation, and MATLAB programming. Open only to Engineering students.

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.

PTE 503 Technology of Unconventional Oil and Gas Resources Development (3, Fa) *Geology of unconventional resources, exploration, development, laboratory testing, drilling, formation evaluation, design and monitoring of hydraulic fracturing, forecasting, technology of oil sand and environmental issues. Open only to graduate students. Recommended preparation:* PTE 507, graduate standing in petroleum engineering.

PTE 504 Geophysics for Petroleum Engineers (3, Sm) *Geosciences concepts and technologies with applications in petroleum engineering: 2D-3D-4D seismic, borehole geophysics, passive seismic, controlled source electromagnetics, geophysical and geological modeling and inversion. Open only to engineering graduate students. Recommended preparation:* familiarity with Matlab.

PTE 505 Inverse Modeling for Dynamic Data Integration (3, Sp) *Introduction to fundamentals of deterministic and stochastic inverse modeling, integration of dynamic data into predictive reservoir models, reservoir parameterization, derivation of adjoint models. Open only to engineering graduate students. Recommended preparation:* PTE 508, basic knowledge of calculus, linear algebra and probability/statistics.

PTE 506 Geothermal Reservoirs (3, Fa) *Geothermal reservoirs, heat and mass flow in fracture network, enhanced geothermal systems (EGS), exploration methods, exploitation of hydrothermal and EGS fields, stimulation, forecasting, power generation. Open only to engineering and geological sciences graduate students. Recommended preparation:* familiarity with Matlab.

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 519 Integrated Physical and Cyber Security for Oil and Gas Operations (3, Fa) Infrastructure Security, Resilience and Management of Digital Oil Fields, Process Control Networks in exploration and production, refining and chemical plants, Asset Integrity principles, case histories. Open only to graduate students.

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, Sm) *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, max 8, FaSpSm) 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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Associate Chair: Erik Johnson, Ph.D.

Director, Environmental Engineering: Amy Childress, Ph.D.

Associate Director, Environmental Engineering: Massoud Pirbazari, Ph.D.

Faculty

Stephen Schrank Early Career Chair in Civil and Environmental Engineering: Burcin Becerik-Gerber, D.Des.

John and Dorothy Shea Early Career Chair in Civil Engineering: Patrick Lynett, Ph.D.

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

Gordon S. Marshall Professor of Engineering Technology: Roger Ghanem, Ph.D. (Aerospace and Mechanical Engineering)

Professors: James C. Anderson, Ph.D.*; Amy Childress, Ph.D.; Roger Ghanem, Ph.D. (Aerospace and Mechanical Engineering); Ronald C. Henry, Ph.D.; Jiin-Jen Lee, Ph.D., P.E.*; Vincent W. Lee, Ph.D.; Sami F. Masri, Ph.D. (Aerospace and Mechanical Engineering); Najmedin Meshkati, Ph.D., CPE (Industrial and Systems Engineering); Massoud Pirbazari, Ph.D.; Constantinos Sioutas, Sc.D.; Lucio Soibelman, Ph.D.; Costas Synolakis, Ph.D. (Aerospace Engineering); Mihailo Trifunac, Ph.D.; L. Carter Wellford, Ph.D.; Hung Leung Wong, Ph.D.*

Associate Professors: Erik A. Johnson, Ph.D.; Patrick Lynett, Ph.D.

Assistant Professors: George Ban-Weiss, Ph.D.; Burcin Becerik-Gerber, D.Des.; Felipe deBarros, Ph.D.; Kelly Sanders, Ph.D.; Ketan Savla, Ph.D.

Professors of Engineering Practice: Gregg E. Brandow Jr., Ph.D., P.E.; Geraldine Knatz, Ph.D. (Public Policy); Henry M. Koffman, P.E.

Associate Professor of Engineering Practice: Amy Rechenmacher, Ph.D.

Senior Lecturer: Dana Sherman, Esq.* (Industrial and Systems Engineering)

Joint Appointments: David J. Gerber, D.Des. (Architecture); Genevieve Giuliano, Ph.D. (Public Policy); Behrokh Khoshnevis, Ph.D. (Industrial and Systems Engineering); James Moffett, Ph.D. (Marine Environmental Biology); James Moore, Ph.D. (Industrial and Systems Engineering, Public Policy); Firdaus E. Udwadia, Ph.D. (Aerospace and Mechanical Engineering); John P. Wilson, Ph.D. (Sociology)

Research Professor: Michael Orosz (Information Sciences Institute)

Research Assistant Professor: Scott Fruin, Ph.D. (Environmental Health, Keck School of Medicine)

Adjunct Associate Professor: Le Dam Hanh-Griffin, Ph.D.

Adjunct Assistant Professor: Navid Nastar, Ph.D.

Adjunct Research Professors: Maria I. Todorovska, Ph.D.; Yan Xiao, Ph.D., P.E.; Dongxiao Zhang, Ph.D.

Adjunct Research Assistant Professors: Jose C. Borrero, Ph.D.; John Caffrey, Ph.D.; Mohammad R. Jahanshahi, Ph.D.; Mazen Wahbeh, Ph.D.

Emeritus Professors: Mihran S. Agbabian, Ph.D., P.E.; George V. Chilingar, Ph.D.; Joseph S. Devinny, Ph.D.; Geoffrey Martin, 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

Undergraduate Program Educational Objectives

Fulfilling the vision of the Sonny Astani Department of Civil and Environmental Engineering, the Viterbi School of Engineering and the University of Southern California, our graduates will:

Be successful in their professional careers, become leaders in industry, academia, government or service, while adapting their technical, collaborative and managerial skills for the benefit of Society's built and natural environments.

Support the advancement of the practice of science and engineering, while maintaining professional standards and moral and legal obligations to society, while being active in professional organizations and obtaining professional licensure when appropriate.

Be prepared to pursue graduate studies in engineering or other disciplines, while continuously broadening their abilities and enhancing their technical skills to maintain their relevance with technological change.

Be successful in their professional careers, become leaders in industry, academia, government or service, while adapting their technical, collaborative and managerial skills for the benefit of Society's built and natural environments.

Support the advancement of the practice of science and engineering, while maintaining professional standards and moral and legal obligations to society, while being active in professional organizations and obtaining professional licensure when appropriate.

Be prepared to pursue graduate studies in engineering or other disciplines, while continuously broadening their abilities and enhancing their technical skills to maintain their relevance with technological change.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Civil Engineering prepares graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry and at least one additional area of basic science, consistent with the program educational objectives; apply knowledge of four technical areas appropriate to civil engineering; conduct civil engineering experiments and analyze and interpret the resulting data; and design a system, component, or process in more than one civil engineering context. The program also explains basic concepts in management, business, public policy,

and leadership; and explains the importance of professional licensure.

The program leading to a Bachelor of Science in Environmental Engineering prepares graduates to be proficient in mathematics through differential equations, probability and statistics, calculus-based physics, general chemistry; an earth science, e.g., geology, meteorology, soil science, relevant to the program of study; a biological science, e.g., microbiology, aquatic biology, toxicology, relevant to the program of study; fluid mechanics relevant to the program of study; and an introductory level knowledge of environmental issues associated with air, land, and water systems and associated environmental health impacts. The program prepares graduates to be proficient at conducting laboratory experiments and critically analyzing and interpreting data in more than one major environmental engineering focus area, e.g., air, water, land, environmental health; performing engineering design by means of design experiences integrated throughout the professional component of the curriculum; and to be proficient in advanced principles and practice relevant to the program objectives; including understanding of concepts of professional practice and the roles and responsibilities of public institutions and private organizations pertaining to environmental engineering.

Undergraduate Degree Programs

Bachelor of Science in Applied Mechanics

The requirement for this degree is 128 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied toward the major, regardless of the department in which the courses are taken. See the common requirements for undergraduate degrees section.

composition/writing requirements		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	4
		8
General Education		**units**
General education* +		24
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
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		**Units**
Aerospace and Mechanical Engineering		
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 235	Dynamics	3
CE 309	Fluid Mechanics	3
Electrical Engineering		
EE 326L	Essentials of Electrical Engineering	4
		24
Major Electives		**Units**
Free electives**		4
Technical electives		28
Approved electives in computer programming		4
Total units:		128

* GE Category VI and WRIT 150 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.

Bachelor of Science in Civil Engineering (131-132 Unit Program)

The department offers a Bachelor of Science degree in Civil Engineering. Additionally, there are three possible areas of emphases within this civil engineering program major. These are building science, environmental engineering and structural engineering. An area of emphasis appears in parentheses after the primary major name on the transcript.

Bachelor of Science in Civil Engineering

The requirement for the degree is 131-132 units. A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied towards the major, regardless of the department in which the courses are taken. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, CE 225, CE 309 and CE 235. See also common requirements for undergraduate degrees.

Composition/writing requirement		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**Units**
General education* +		20
Pre-major requirements		**Units**
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Other Requirements		
GEOL 305Lx	Introduction to Engineering Geology, or	
BISC 220L	General Biology: Cell Biology and Physiology	4
Major requirements		**Units**
Engineering		
ENGR 102	Engineering Freshman Academy	2
Civil Engineering		

CE 106	Design and Planning of Civil Engineering Systems, or	2
CE 110	Introduction to Environmental Engineering	3
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 235	Dynamics	3
CE 309	Fluid Mechanics	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
		60-61
major electives		**Units**
Elective	Civil Engineering	6
Design Kernel***	Civil Engineering Design Kernel Course	6
Total units:		131-132

* GE Category VI is taken concurrently with WRIT 150.

** 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. CE 460 is a required elective. The other civil engineering elective must be chosen from the following list: CE 461, CE 462, CE 469 and CE 470.

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 and CE 490.

All curricula leading to a degree must be approved by the Astani Department of Civil and Environmental Engineering; 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 Emphasis in Structural Engineering

The requirement for the degree with an emphasis in structural engineering is 131-132 units. A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied towards the major, regardless of the department in which the courses are taken. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, CE 225, CE 309 and CE 235. See also common requirements for undergraduate degrees.

COMPOSITION/WRITING REQUIREMENTS		UNITS
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**UNITS**
General education* +		20
PRE-MAJOR REQUIREMENTS		**UNITS**
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Other Requirements		
GEOL 305Lx	Introduction to Engineering Geology	4
		32
MAJOR REQUIREMENTS		**UNITS**
Engineering		
ENGR 102	Engineering Freshman Academy	2
Civil Engineering		
CE 106	Design and Planning of Civil Engineering Systems, or	2
CE 110	Introduction to Environmental Engineering	3
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 235	Dynamics	3
CE 309	Fluid Mechanics	3
CE 334L	Mechanical Behavior of Materials	3
CE 358	Theory of Structures I	3
CE 402	Computer Methods in Engineering	3
CE 408	Risk Analysis in Civil Engineering	3

CE 451	Water Resources Engineering	3
CE 456	Design of Steel Structures	3
CE 457	Reinforced Concrete Design	3
CE 458	Theory of Structures II	3
CE 459	Introduction to Structural Dynamics	3
CE 460	Construction Engineering	3
CE 467L	Geotechnical Engineering	4
CE 473	Engineering Law, Finance, and Ethics	3
Capstone Courses		
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
		69-70
MAJOR ELECTIVES		**UNITS**
Elective***	Civil Engineering	3
Total units:		131-132

* GE Category VI is taken concurrently with WRIT 150.

** 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.

All curricula leading to a degree must be approved by the Astani Department of Civil and Environmental Engineering; 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 Emphasis in Building Science

The requirement for the degree with an emphasis in building science is 135-136 units. A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied towards the major, regardless of the department in which the courses are taken. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, CE 225, CE 309 and CE 235. See also the common requirements for undergraduate degrees section.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**UNITS**
General education* +		20
PRE-MAJOR REQUIREMENTS		**UNITS**
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II:	4

	Electricity and Magnetism	
Other Requirements		
GEOL 305Lx	Introduction to Engineering Geology	4
MAJOR REQUIREMENTS		**UNITS**
Engineering		
ENGR 102	Engineering Freshman Academy	2
Civil Engineering		
CE 106	Design and Planning of Civil Engineering Systems, or	2
CE 110	Introduction to Environmental Engineering	3
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 235	Dynamics	3
CE 309	Fluid Mechanics	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	3
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:		135-136

* GE Category VI is taken concurrently with WRIT 150.

** 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.

All curricula leading to a degree must be approved by the Astani Department of Civil and Environmental Engineering; 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 Emphasis in Environmental Engineering

The requirement for the degree with an emphasis in environmental engineering is 129-130 units. A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied

toward the major, regardless of the department in which the courses are taken. In addition, a minimum grade of C must be earned in each of the following courses: CE 205, CE 225, CE 309 and CE 235. See also common requirements for undergraduate degrees.

composition/Writing requirement		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**Units**
General education* +		20
pre-major requirements		**Units**
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
Other Requirement		
BISC 220L	General Biology: Cell Biology and Physiology, or	
GEOL 305Lx	Introduction to Engineering Geology	4
major requirements		**Units**
Engineering		
ENGR 102	Engineering Freshman Academy	2
Civil and Environmental Engineering		
CE 106	Design and Planning of Civil Engineering Systems, or	2
CE 110	Introduction to Environmental Engineering	3
CE 108	Introduction to Computer Methods in Civil Engineering	2
CE 205	Statics	2
CE 210L	Introduction to Environmental Engineering Microbiology	3
CE 225	Mechanics of Deformable Bodies	3
CE 235	Dynamics	3
CE 309	Fluid Mechanics	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
Aerospace and Mechanical Engineering		
AME 310	Engineering Thermodynamics I	3
		60-61
major elective		**Units**
Design kernel***		6
Total units:		129-
		130

GE Category VI is taken concurrently with WRIT 150.

** 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.

All curricula leading to a degree must be approved by the Astani Department of Civil and Environmental Engineering; 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 (131-134 Unit Program)

The program has two tracks: Track 1: Environmental Systems and Processes (131-132 units); Track II: Environmental Biotechnology (133-134 units). A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied towards the major, regardless of the department in which the courses are taken. 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.

COMPOSITION/WRITING REQUIREMENT		UNITS
WRIT 150*	Writing and Critical Reasoning	4
WRIT 340	Advanced Writing	3
General Education		**UNITS**
General education* +		20
PRE-MAJOR REQUIREMENTS (Both Tracks)		**UNITS**
Chemistry Requirement		
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
CHEM 105bL	General Chemistry, or	
CHEM 115bL	Advanced General Chemistry	4
CHEM 322aL	Organic Chemistry	4
Math Requirement		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 226	Calculus III	4
MATH 245	Mathematics of Physics and Engineering I	4
Physics Requirement		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism	4
		36
PRE-MAJOR REQUIREMENTS (Track II only)		**UNITS**
Chemistry Requirement		
CHEM 322bL	Organic Chemistry	4
MAJOR REQUIREMENTS (Both Tracks)		**UNITS**
Engineering		
ENGR 102	Engineering Freshman Academy	2
Civil and Environmental Engineering		
CE 106	Design and Planning of Civil Engineering Systems, or	2
CE 110	Introduction to Environmental Engineering	3
CE 108	Introduction to Computer Methods in Civil Engineering	2
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
Courses from Other Departments		
CHE 330	Chemical Engineering Thermodynamics	4
GEOL 305Lx	Introduction to Engineering Geology	4
		55-56
MAJOR REQUIREMENTS (Track I Only)		**UNITS**
Civil and Environmental Engineering		
ENE 429	Air Pollution Control	3
Courses from Other Departments		
BISC 220L	General Biology: Cell Biology and Physiology	4
PTE 463L	Introduction to Transport Processes in Porous Media	3
		10
MAJOR REQUIREMENTS (Track II Only)		**UNITS**
Civil and Environmental Engineering		
ENE 487	Environmental Biotechnology and Bioremediation	3
Courses from Other Departments		
BISC 320L	Molecular Biology	4
BISC 330L	Biochemistry	4
		11
MAJOR ELECTIVES (Track I Only)		**UNITS**
Design kernel***		3
Total (Track I):		131-132
Total (Track II):		133-134

GE Category VI is taken concurrently with WRIT 150.

** 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 Environmental Engineering.

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 Dornsife College of Letters, Arts and Sciences.

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

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 adviser approved course in statistics. Candidate courses include ECON 317, EE 364, ISE 220, MATH 208, PPD 303, PSYC 274L, 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	Sustainable Design and Construction, or	
CE 470	Building Information Modeling and Integrated Practice	3
Theme Requirement: Two courses, both from Theme 1 or Theme 2 or Theme 3		
Theme 1		
PPD 358	Urban and Regional Economics	4
PPD 362	Real Estate Fundamentals for Planning and Development	4
Theme 2		
FBE 400x	Introduction to Real Estate Finance and Development	4
FBE 466	Management of Real Estate Development: Feasibility Studies	4
Theme 3		
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

* Prerequisite required.

Advisement is provided by the Astani Department of Civil and Environmental Engineering. Students will normally complete statistics before enrolling in CE 461 but can be permitted to complete statistics as a corequisite subject to adviser approval. Students are advised to take CE 460 and CE 461 before taking CE 462. Students electing PPD 437 must have completed PPD 362.

Graduate Programs

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; structural 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 Price School of Public Policy. For further information, see the Public Administration Professional Sequence section in the USC Price School of Public Policy.

Master of Science in Civil Engineering (Transportation Systems)

See Sustainable Infrastructure Systems.

Master of Science in Civil Engineering (Water and Waste Management)

See Sustainable Infrastructure Systems.

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 adviser and program director. Selection of courses will be determined through consultation with a program adviser to provide a maximum of training in the student's area of interest in environmental problems.

Master of Construction Management

Students possessing a bachelor's degree and with sufficient training in capital management and statistics may pursue the Master of Construction Management. 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 program is drawn from the M.S., Civil Engineering program in construction engineering and management, and from the USC 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	Building Systems: Materials and Construction	4
CE 501	Functions of the Constructor	3
CE 502	Construction Accounting and Finance, or	3
ACCT 509	Concepts of Financial and Management Accounting, or	4
ISE 566	Financial Accounting Analysis for Engineering	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, or track 3		**units**
Track 1: Finance Track		
FBE 400x*	Introduction to Real Estate Finance and Development	4
FBE 489	Real Estate Capital Markets	4
FBE 570*	Advanced Topics in Real Estate Finance	3
FBE 589*	Mortgages and Mortgage-Backed Securities and Markets	3
FBE 591*	Real Estate Finance and Investment	3
Track 2: Real Estate Development Track		
FBE 466*	Management of Real Estate Development: Feasibility Studies	4
FBE 470*	Advanced Real Estate Analysis	4
FBE 565	Economics of Urban Land Use: Feasibility Studies	3
FBE 566	Real Estate Finance, Investments and Development	3
Track 3: Architecture, Engineering and Construction (AEC) Technology Track		
CE 470	Building Information Modeling and Integrated Practice	3
CE 469	Sustainable Design and Construction, or	
CE 570	Building Information Modeling for Collaborative Construction	3
Additional adviser-approved technical and advanced electives		10-11
Total minimum units		33

*Prerequisite required.

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 USC Astani Department of Civil and Environmental Engineering, other engineering departments, the USC Price School of Public Policy, 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 adviser 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 Astani Department in writing. Such leaves may be granted for up to one year.

Engineer in Civil Engineering

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

Doctor of Philosophy in Civil Engineering and Doctor of Philosophy in Engineering (Environmental Engineering)

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

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

Graduate Certificate in Transportation Systems

The graduate certificate in Transportation Systems is an interdisciplinary program administered by the USC Astani Department of Civil and Environmental 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 USC Astani Department of Civil and Environmental Engineering. Course prerequisites for the program are:

- one course in statistics or uncertainty, equivalent to ISE 225, PPD 404x or CE 408;

- one course in engineering economy, equivalent to ISE 460;

- one course in microeconomics, equivalent to ECON 203; and

- 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 USC Astani Department of Civil and Environmental 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 205; corequisite: CE 107 and 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 106 or 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 235 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. (Duplicates credit in CE 325.) 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 235.

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, CHEM 105aL or CHEM 115aLg and PHYS 152L.*

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 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 409abL 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 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.) Prerequisite: CE 225.

CE 469 Sustainable Design and Construction (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 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 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. Prerequisite: CE 207, CE 225.

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 485 Wastewater Treatment Design (3, Sp)
Process kinetics, mass balance, reactor design, pretreatment, clarification, chemical treatment, biological treatment (aerobic and anaerobic), disinfection, sludge treatment, nitrogen and phosophorus removal, carbon adsorption. Prerequisite: CE 451, CE 463L, CE 473.

CE 490x Directed Research (1-8, max 12)
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 CR/NC. 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 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 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; acquifer 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, Sm) *Physical, chemical, and biological treatment processes for industrial and hazardous wastes; pretreatment systems, biodegradation of toxic chemicals; groundwater and soil decontamination; biofilters for air decontamination. Prerequisite: CE 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. Prerequisite: a: CE 309 or ENE 410.

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 525 Engineering Mathematical Analysis (3, Sp) Engineering problems discussed on a physical basis with solutions via mathematical tools: Vector analysis; functions of complex variables, infinite series, residues and conformal mappings. (Duplicates credit in the former CE 525a.)

CE 526 Engineering Mathematical Methods (3)
Engineering problems discussed on a physical basis with solutions via mathematical tools: Fourier series; Fourier and Laplace transforms; partial differential equations, wave and Laplace equations. (Duplicates credit in the former CE 525b.) Recommended preparation: undergraduate multivariable calculus and ordinary differential equations.

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 535 Earthquake Engineering: Strong Motion Studies (3, Fa) Earthquake source mechanisms; wave propagation, scattering, diffraction and amplification; empirical scaling of strong ground motion; seismic hazard analysis for earthquake resistant design codes and mapping. (Duplicates credit in former CE 535a.)

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 547 Earthquake Engineering: Response of Structures (3, Sp) Solutions of seismic structural response: vibrational vs. wave methods, spectral superposition, probabilistic response estimation, nonlinear response; soil-structure interaction; identification and structural health monitoring; experimental methods. (Duplicates credit in former CE 535b.)

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, FaSpSm) *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 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 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 567 Smart Infrastructures (3) Examination of smart infrastructures relating to energy, water, waste and transportation drawing from the fields of engineering, sustainability, communications, sociology, and psychology.

CE 570 Building Information Modeling for Collaborative Construction (3, Sp) Multidisciplinary 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 571 Nuclear Safety and Security: Human Performance and Safety Culture (3) Provides an overview of human-systems integration considerations, human performance and safety culture in the nuclear power operations.

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 581 Negotiation For Engineering Management (3, Sp) (Enroll in ISE 581)

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. Recommended preparation: CE 471 and CE 457; probability and statistics on the level of CE 408.

CE 584 Intelligent Transportation Systems (3) Fundamentals of intelligent transportation systems, automated vehicles, communication systems, connected vehicle technologies, mobile devices, policy and planning, international research, standards, architecture, and economics of ITS.

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 588 Railroad Engineering (3) Railroad infrastructure including passenger and freight operations, track alignment (horizontal and vertical) design, basic components and terminology used in rail design and an understanding of this mode of transportation. Recommended preparation: CE 471.

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 638 Stochastic Optimization (3, FaSp) (Enroll in ISE 638)

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 647 Multiscale Methods in Mechanics (3) Behavior of man-made and natural materials at different scales; experimental methods to characterize behavior; governing equations, interscale coupling, information exchange; probabilistic representations; error analysis. Open only to master's, doctoral, and professional students. Prerequisite: AME 525 or AME 526 or CE 525 or CE 526.

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 692 Transportation and the Environment (4) (Enroll in PPD 692)

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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Associate Chair: Erik Johnson, Ph.D.

Director, Environmental Engineering: Amy Childress, Ph.D.

Associate Director, Environmental Engineering: Massoud Pirbazari, Ph.D.

Faculty

Stephen Schrank Early Career Chair in Civil and Environmental Engineering: Burcin Becerik-Gerber, D.Des.

John and Dorothy Shea Early Career Chair in Civil Engineering: Patrick Lynett, Ph.D.

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

Gordon S. Marshall Professor of Engineering Technology: Roger Ghanem, Ph.D. (Aerospace and Mechanical Engineering)

Professors: James C. Anderson, Ph.D.*; Amy Childress, Ph.D.; Roger Ghanem, Ph.D. (Aerospace and Mechanical Engineering); Ronald C. Henry, Ph.D.; Jiin-Jen Lee, Ph.D., P.E.; Vincent W. Lee, Ph.D.; Sami F. Masri, Ph.D. (Aerospace and Mechanical Engineering); Najmedin Meshkati, Ph.D., CPE (Industrial and Systems Engineering);

Massoud Pirbazari, Ph.D.; Constantinos Sioutas, Sc.D.; Lucio Soibelman, Ph.D.; Costas Synolakis, Ph.D. (Aerospace Engineering); Mihailo Trifunac, Ph.D.; L. Carter Wellford, Ph.D.; Hung Leung Wong, Ph.D.*

Associate Professors: Erik A. Johnson, Ph.D; Patrick Lynett, Ph.D.

Assistant Professors: George Ban-Weiss, Ph.D.; Burcin Becerik-Gerber, D.Des.; Felipe de Barros, Ph.D.; Kelly Sanders, Ph.D.; Ketan Savla, Ph.D.

Professors of Engineering Practice: Gregg E. Brandow Jr., Ph.D., P.E.; Geraldine Knatz, Ph.D. (Public Policy); Henry M. Koffman, P.E.

Associate Professor of Engineering Practice: Amy Rechenmacher, Ph.D.

Senior Lecturer: Dana Sherman, Esq.* (Industrial and Systems Engineering)

Joint Appointments: David J. Gerber, D.Des. (Architecture); Genevieve Giuliano, Ph.D. (Public Policy); Behrokh Khoshnevis, Ph.D. (Industrial and Systems Engineering); James Moffett, Ph.D. (Marine Environmental Biology); James Moore, Ph.D. (Industrial and Systems Engineering, Public Policy); Firdaus E. Udwadia, Ph.D. (Aerospace and Mechanical Engineering); John P. Wilson, Ph.D. (Sociology)

Research Professor: Michael Orosz (Information Sciences Institute)

Research Assistant Professor: Scott Fruin, Ph.D. (Environmental Health, Keck School of Medicine)

Adjunct Associate Professor: Le Dam Hanh-Griffin, Ph.D.

Adjunct Assistant Professor: Navid Nastar, Ph.D.

Adjunct Research Professors: Maria I. Todorovska, Ph.D.; Yan Xiao, Ph.D., P.E.; Dongxiao Zhang, Ph.D.

Adjunct Research Assistant Professors: Jose C. Borrero, Ph.D.; John Caffrey, Ph.D.; Mohammad R. Jahanshahi, Ph.D.; Mazen Wahbeh, Ph.D.

Emeritus Professors: Mihran S. Agbabian, Ph.D., P.E.; George V. Chilingar, Ph.D.; Joseph S. Devinny, Ph.D.; Geoffrey Martin, Ph.D.

*Recipient of university-wide or school teaching award.

Degree Requirements

Undergraduate Program Educational Objectives

Fulfilling the vision of the Sonny Astani Department of Civil and Environmental Engineering, the Viterbi School of Engineering and the University of Southern California, our graduates will:

Be successful in their professional careers, become leaders in industry, academia, government or service, while adapting their technical, collaborative and managerial skills for the benefit of Society's built and natural environments.

Support the advancement of the practice of science and engineering, while maintaining professional standards and moral and legal obligations to society, while being active in professional organizations and obtaining professional licensure when appropriate.

Be prepared to pursue graduate studies in engineering or other disciplines, while continuously broadening their abilities and enhancing their technical skills to maintain their relevance with technological change.

Be successful in their professional careers, become leaders in industry, academia, government or service, while adapting their technical, collaborative and managerial skills for the benefit of Society's built and natural environments.

Support the advancement of the practice of science and engineering, while maintaining professional standards and moral and legal obligations to society, while being active in professional organizations and obtaining professional licensure when appropriate.

Be prepared to pursue graduate studies in engineering or other disciplines, while continuously broadening their abilities and enhancing their technical skills to maintain their relevance with technological change.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Civil Engineering prepares graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry and at least one additional area of basic science, consistent with the program educational objectives; apply knowledge of four technical areas appropriate to civil engineering; conduct civil engineering experiments and analyze and interpret the resulting data; and design a system, component, or process in more than one civil engineering context. The program also explains basic concepts in management, business, public policy, and leadership; and explains the importance of professional licensure.

The program leading to a Bachelor of Science in Environmental Engineering prepares graduates to be proficient in mathematics through differential equations, probability and statistics, calculus-based physics, general chemistry; an earth science, e.g., geology, meteorology, soil science, relevant to the program of study; a biological science, e.g., microbiology, aquatic biology, toxicology, relevant to the program of study; fluid mechanics relevant to the program of study; and an introductory level knowledge of environmental issues associated with air, land, and water systems and associated environmental health impacts. The program prepares graduates to be proficient at conducting laboratory experiments and critically analyzing and interpreting data in more than one major environmental engineering focus area, e.g., air, water, land, environmental health; performing engineering design by means of design experiences integrated throughout the professional component of the curriculum; and to be proficient in advanced principles and practice relevant to the program objectives; including understanding of concepts of professional practice and the roles and responsibilities of public institutions and private organizations pertaining to environmental engineering.

Bachelor of Science in Environmental Engineering

See 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 Emphasis in Environmental Engineering

See Civil Engineering.

Master of Science in Environmental Engineering

See Civil Engineering.

Engineer in Environmental Engineering

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

Ph.D. in Engineering (Environmental Engineering)

See listing under Civil Engineering.

Sustainable Cities Graduate Certificate

See the listing in the USC Price School of Public Policy section.

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: MATH 245, PHYS 151L, CHEM 105bL or CHEM 115bL; recommended preparation: ENE 400 or CHE 350.*

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

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

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

Undergraduate Program Educational Objectives

Graduates of the Computer Engineering and Computer Science program are expected to attain the following educational objectives within a few years of graduation:

- Graduates will apply analytical and critical thinking principles of both computer engineering and computer science to their chosen professions.

- Graduates will successfully engage in life-long learning to continue to be contributing members of their communities in fields within and outside the traditional scope of computer engineering.

- Graduates will exhibit high professional and ethical standards to become productive leaders in society.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Computer Engineering and Computer Science provides both breadth and depth across the range of engineering topics implied by the title. The curriculum includes probability and statistics, including appropriate applications; mathematics, including discrete mathematics through differential and integral calculus; sciences (defined as biological, chemical or physical science) to develop an understanding of the scientific method and provide students with an opportunity to experience this mode of inquiry in courses for science or engineering majors that provide some exposure to lab work; and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software and systems containing hardware and software components.

The computer science portion of the curriculum covers the fundamentals of algorithms, data structures, software design, concepts of programming languages and computer organization and software; provides an exposure to a variety of programming languages and systems, including at least one higher-level language; and includes advanced course work that builds on the fundamental course work to provide depth.

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.

The requirement for the degree is 128 units. A cumulative grade point average of C (2.0) is required in all upper division courses applied toward the major,

regardless of the department in which the courses are taken.

composition/writing requirements (7 units)		Units
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340*	Advanced Writing	3
General Education (20 units)		**Units**
General education+		20
Pre-Major Requirements (29-30 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (16 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Differential Equations	4
MATH 226	Calculus III	4
Statistics and Probability (3-4 units)		
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science (3), or	
MATH 407	Probability Theory (4)	3-4
Physics (8 units)		
PHYS 151L**	Fundamentals of Physics I: Mechanics and Thermodynamics, and	4
PHYS 152L	Fundamentals of Physics II: Electricity and Magnetism; or	4
PHYS 161L	Advanced Principles of Physics I, and	4
PHYS 162L	Advanced Principles of Physics II	4
major requirements (51-52 units)		**Units**
Computer Science (27 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 350	Introduction to Operating Systems	4
CSCI 353	Introduction to Internetworking	4
Electrical Engineering (21 units)		
EE 109	Introduction to Embedded Systems	3
EE 154	Fundamentals of Digital Logic	2
EE 254	Introduction to Digital Circuits	4
EE 277	Introduction to Digital Integrated Circuits	2
EE 451	Parallel and Distributed Computation	3
EE 457	Computer Systems Organization	3
And one of the following courses:		
EE 454	Introduction to Systems Using Microprocessors (4), or	
EE 477L	MOS VLSI Circuit Design (4)	4
Senior Design Project (3-4 units)		
CSCI 477ab	Design and Construction of Large Software Systems (2-2), or	
EE 459L	Embedded Systems Design Laboratory (3)	3-4
Engineering Economy/Business elective		3-4
Technical electives ++		11
Free electives		5-7
Total Units		128

** Satisfies GE requirement.

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

++ *Technical Electives (11 units) Applicable courses include: CSCI 300, CSCI 310, CSCI 360, CSCI 420, CSCI 445L, CSCI 459, CSCI 460, CSCI 464, CSCI 476, CSCI 477ab, CSCI 485, CSCI 490x, CSCI 491ab, CSCI 499; EE 454L, EE 465, EE 477L, EE 459L, EE 477L, EE 490x, EE 499; MATH 458. Students may also choose one adviser-approved course from the 300- and 400-level ITP offerings. Other courses may be applicable; please see an adviser 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 adviser-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 adviser 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 or EE 503):

Fundamental Courses		Units
CSCI 402x	Operating Systems	3
EE 450	Introduction to Computer Networks, or	
EE 465	Probabilistic Methods in Computer Systems Modeling	3
EE 457	Computer Systems Organization	3
EE 477L	MOS VLSI Circuit Design	4
EE 503	Probability for Electrical and	4

Computer Engineers

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	
EE 555	Broadband Network Architectures	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.) 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:		
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.		
Theory Area Courses		
CSCI 570	Analysis of Algorithms	3
EE 465	Probabilistic Methods in Computer Systems Modeling, or	
EE 503	Probability for Electrical and Computer Engineers, or	
EE 549	Queuing Theory for Performance Modeling	3-4
EE 562a	Random Processes in Engineering	3
EE 565a	Information Theory	3
MATH 410	Fundamental Concepts of Modern Algebra, or	
MATH 425a	Fundamental Concepts of Analysis	4
MATH 432	Applied Combinatorics, or	
MATH 533	Combinatorial Analysis and Algebra	4
Hardware Area Courses		
EE 536a	Mixed Signal Integrated Circuit Design	3
EE 552	Asynchronous VLSI Design	3
EE 557	Computer Systems Architecture	3
Software Area Courses		

CSCI 565	Compiler Design, or	
CSCI 595	Advanced Compiler Design	4
CSCI 577a	Software Engineering	4
CSCI 585	Database Systems	3
Systems Area Courses		
CSCI 551	Computer Communications	3
CSCI 555	Advanced Operating Systems	3
CSCI 561	Foundations of Artificial Intelligence	3
EE 543a	Digital Control Systems	3
EE 554	Real Time Computer Systems	3
EE 550	Design and Analysis of Computer Communication Networks, or	
EE 555	Broadband Network Architectures	3
EE 569	Introduction to Digital Image Processing	3

Computer Science

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

Chair: Gaurav Sukhatme, Ph.D.

Faculty

Chan Soon-Shiong Chair: Maja Matarić, Ph.D. (Neuroscience Center)

Dean's Chair in Chemical Engineering and Materials Science: Priya Vashishta, Ph.D. (Computer Science, Physics)

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

Viterbi Early Career Chair: Jernej Barbic, Ph.D.

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

Jack Munishian Early Career Chair: Fei Sha, Ph.D.

Northrup Grumman Chair in Engineering: Ramesh Govindan, 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. (Electrical Engineering)

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.

Dean's Professor of Computer Science: Kevin Knight, Ph.D

Dean's Professor of Computer Science: Gaurav Sukhatme, Ph.D

Helen N. & Emmett H. Jones Professorship in Engineering: Milind Tambe, Ph.D. (Industrial and Systems Engineering)

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

TRW Professor of Software Engineering: Barry Boehm, Ph.D.

WISE Jr. Gabilan Chair in Computer Science: Nora Ayanian, 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); Leana Golubchik, Ph.D. (Electrical Engineering); Ramesh Govindan, Ph.D.; Ellis Horowitz, Ph.D. (Electrical Engineering); Ming-Deh Huang, Ph.D.; Laurent Itti, Ph.D. (Neuroscience Center); Sven Koenig, Ph.D.; Kevin Knight, Ph.D.; Maja Matarić, Ph.D. (Neuroscience Center); Dennis McLeod, Ph.D.; Gerard Medioni, Ph.D. (Electrical Engineering); Neno Medvidovic, Ph.D.; 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.; Stefan Schaal, Ph.D. (Neuroscience Center); Cyrus Shahabi, Ph.D.; Gaurav Sukhatme, Ph.D. (Electrical Engineering); Milind Tambe, Ph.D. (Industrial and Systems Engineering); Shanghua Teng, Ph.D.

Associate Professors: Shahram Ghandeharizadeh, Ph.D.; David Kempe, Ph.D.; Fei Sha, Ph.D.

Assistant Professors: Nora Ayanian, Ph.D.; Jernej Barbic, Ph.D.; Shaddin Dughmi, Ph.D.; William GJ Halfond, Ph.D.; Hao Li, Ph.D.; Wyatt Lloyd, Ph.D; Ethan Katz-Bassett, Ph.D.; Yan Liu, Ph.D.; Minlan Yu, Ph.D.

Joint Professors: Murali Annavaram, Ph.D. (Electrical Engineering); Irving Biederman, Ph.D. (Psychology); Melvin Breuer, Ph.D. (Electrical Engineering); Todd Brun, Ph.D.; Tim Ting Chen, Ph.D. (Biological Sciences); Michael Crowley, Ph.D. (Information Technology Program); 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); Urbashi Mitra, Ph.D. (Electrical Engineering); Shrikanth (Shri) Narayanan, Ph.D. (Electrical Engineering); Hamid Nazerzadeh, Ph.D. (Data Sciences and Operations); Viktor Prasanna, Ph.D. (Electrical Engineering); Konstantinos Psounis, Ph.D.; C.S. Raghavendra, Ph.D. (Electrical Engineering); Benjamin Reichardt, Ph.D. (Electrical Engineering); Remo Rohs, Ph.D. (Computational Biology); Nicolas Schweighofer, Ph.D. (Biokinesiology and Physical Therapy); Mark S. Seidenberg, Ph.D. (Psychology, Linguistics); Francisco Valero-Cuevas (Biomedial Engineering); Priya Vashishta, Ph.D. (Chemical Engineering and Materials Science, Physics); Michael Waterman, Ph.D. (Mathematics, Biological Sciences); Richard Weinberg, Ph.D. (Cinematic Arts); John Wilson, Ph.D. (Geography); Xianghong Zhou, Ph.D. (Biological Sciences)

Adjunct Professors: Danny Cohen, Ph.D.; Mary Hall, Ph.D.; Rick Selby, Ph.D.

Adjunct Associate Professors: Steve Chien, Ph.D.; Larry Matthies, Ph.D.; Chris Mattmann, Ph.D.; Zhengyou Zhang, Ph.D.

Adjunct Assistant Professors: Aude Billard, Ph.D.; Auke Ijspeert, Ph.D.; Marco Papa, Ph.D.; Sethu Vijayakumar, Ph.D.; Roger Zimmermann, Ph.D.

Research Professors: Paul Debevec, Ph.D.; Yolanda Gil, Ph.D.; Jonathan Gratch, Ph.D.; John Heidemann, Ph.D.; Randall Hill, Ph.D.; Jerry Hobbs, Ph.D.; Craig Knoblock, Ph.D.; Premkumar Natarajan, Ph.D.; Herbert Schorr, Ph.D.; William Swartout, Ph.D.

Research Associate Professors: Ann L. Chervenak, Ph.D.; Ewa Deelman, Ph.D.; Andrew Gordon, Ph.D.; Eduard Hovy, Ph.D.; Kristina Lerman, 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.; Ron Artstein Ph.D.; Yu-Han Chang, Ph.D.; Young Cho, Ph.D.; Morteza Dehghani, Ph.D.; David DeVault, Ph.D.; Pedro Diniz, Ph.D.; Aram Galstyan, Ph.D.; Kallirroi Georgila, Ph.D.; Jihie Kim, Ph.D.; Anton Leuski, Ph.D.; Rajiv Maheswaran, Ph.D.; Jelena Mirkovic, Ph.D.; Louis-Philippe Morency, Ph.D.; Kenji Sagae, Ph.D.; Evan Suma, Ph.D.; Pedro Szekely, Ph.D.; David Traum, Ph.D.; Greg Ver Steeg, Ph.D.; Suya You, Ph.D.

Professor of Engineering Practice: Michael Zyda, Ph.D.

Associate Professor of Engineering Practice: Jeffrey Miller, Ph.D.; Michael Zyda, Ph.D.

Lecturers: Claire Bono; William Cheng, Ph.D.; Aaron Cote, Ph.D.; Scott Easley, B.A.; Massoud Ghyám-Khah, Ed.D.; Jeffrey Miller, Ph.D. (Associate Professor of Engineering Practice); Shawn Shamsian, Ph.D.; Sheila Tejada, Ph.D. (Senior Lecturer); Michael Zyda, Ph.D. (Professor of Engineering Practice)

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

Bachelor of Science

Undergraduate Program Educational Objectives

Graduates of the undergraduate program in Computer Science are expected to attain the following objectives within a few years of graduation:

(1) Graduates apply the computational and analytical approaches of computer science to their chosen professions.

(2) Graduates successfully engage in life-long learning to continue to be contributing members of their communities in fields within and outside the traditional scope of computer science.

(3) Graduates exhibit high professional and ethical standards to become productive leaders in society.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Computer Science includes at least one and one-third years of computer science that covers the fundamentals of algorithms, data structures, software design, concepts of programming languages and computer organization and software; provides an exposure to a variety of programming languages and systems, including at least one higher-level language; and includes advanced course work that builds on the fundamental course work to provide depth.

The program includes at least one year of science and mathematics, including at least one-half year of mathematics, including discrete mathematics. Additional mathematics might consist of calculus, linear algebra, numerical methods, probability, statistics, number theory, geometry, or symbolic logic. The science component develops an understanding of the scientific method and provides an opportunity to experience this mode of inquiry in courses for science or engineering majors that provide some exposure to laboratory work.

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 grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied towards the major, regardless of the department in which the courses are taken. Candidates must complete general education requirements; see The USC Core and the General Education Program.

Composition/Writing requirement (7 units)		units
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340*	Advanced Writing	3
General Education (20 units)		**Units**
General education+		20
pre-Major requirements (33-34 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (16 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
MATH 225	Linear Algebra and Differential Equations	4
MATH 226	Calculus III	4
Statistics and Probability (3-4 units)		
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science, or	
MATH 407	Probability Theory	3-4
Basic Science (8 units)		
One of the following science area course sequences:		
Biology: BISC 120L** and BISC 220L or BISC 121L** and BISC 221L		
Chemistry: CHEM 105abL** or CHEM 115abL**		
Physics: PHYS 151L** and PHYS 152L or PHYS 161L and PHYS 162L		8
Other Requirements		
Science elective***		4
Major Requirements (68 units)		**Units**
Computer Science (38 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 310	Introduction to Software Engineering	4
CSCI 350	Introduction to Operating Systems	4
CSCI 360	Introduction to Artificial Intelligence	4
CSCI 477ab	Design and Construction of Large Software Systems	2-2
Electrical Engineering (6 units)		
EE 101	Introduction to Digital Logic	3
Technical electives++ (at least four courses for a minimum of 14 units)		14
Free electives		10
Total units		128
Composition/Writing requirement (7 units)		**units**
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340*	Advanced Writing	3
General		Units

Education (20 units)		
General education+		20
pre-Major requirements (17-18 units)		units
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
Linear Algebra (3-4 units)		
MATH 225	Linear Algebra and Linear Differential Equations, or	4
EE 241	Applied Linear Algebra for Engineering	3
Physics (4 units)		
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics, or	4
PHYS 161L	Advanced Principles of Physics	4
MAJOR REQUIREMENTS (84 UNITS)		**units**
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 350	Introduction to Operating Systems	4
CSCI 353	Introduction to Internetworking	4
CSCI 360	Introduction to Artificial Intelligence	4
CSCI 420	Computer Graphics	4
CSCI 423	Native Console Multiplayer Game Development	4
CSCI 425	Immersive Game Design	4
EE 352L	Computer Organization and Architecture	4
Game Development (31 UNITS)		**units**
CTIN 190	Introduction to Interactive Entertainment	4
CSCI 281	Pipelines for Games and Interactives	3
CSCI 491abL	Final Game Project (4-2)	6
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
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4
Total units		128-129
COMPOSITION/WRITING REQUIREMENT (7 UNITS)		**UNITS**
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
general education (20 UNITS)		**UNITS**
General education		20
Pre-Major requirements (14 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
*Basic Science (4 units)**		

PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics, or	
PHYS 161L	Advanced Principles of Physics, or	4
BISC 120L	General Biology: Organismal Biology and Evolution, or	
BISC 121L	Advanced General Biology: Organismal Biology and Evolution, or	4
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Major Requirements (88-90 units)		**Units**
Statistics and Probability (3-4 units)		
BUAD 310	Applied Business Statistics (4), or	
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science (3), or	
MATH 407	Probability Theory (4)	3-4
Linear Algebra (3-4 units)		
EE 241	Applied Linear Algebra for Engineering (3), or	
MATH 225	Linear Algebra and Linear Differential Equations (4)	3-4
Computer Science Requirements (30 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 310	Introduction to Software Engineering	4
CSCI 477ab	Design and Construction of Large Software Systems (2-2)	4
Computer Science Electives (8 units minimum)		
Take one of the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 360L	Introduction to Artificial Intelligence	4
CSCI 430	Security Systems	4
CSCI 485	File and Database Management	3
And take one approved Computer Science elective (see adviser)		4
Business Requirements (36 units)		
ACCT 410x	Accounting for Non-Business Majors	4
BUAD 302	Communication Strategy in Business	4
BUAD 304	Organizational Behavior and Leadership	4
BUAD 306	Business Finance	4
BUAD 307	Marketing Fundamentals	4
BUAD 311	Operations Management	4
BUAD 497	Strategic Management	4
ECON 351x	Microeconomics for Business	4
ECON 352x	Macroeconomics for Business	4
Business Electives (8 units)		
Take two of the following courses:		
BAEP 452	Feasibility Analysis	4
BAEP 453	Venture Management	4
BUAD 301	Technical Entrepreneurship	3
DSO 431	Managing the Digital Revolution for Your Business	4
DSO 433	Business Information Systems Analysis and Design	4
DSO 443	The Business of Interactive Digital Media	4
DSO 462	Managing a Small Business	4

	on the Internet	
MKT 425	Marketing on the Internet	4
Total units		129-131
Required Courses		**units**
Lower division (18 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development (3), or	
CSCI 270	Introduction to Algorithms and Theory of Computing (4)	3-4
Electives		**units**
12 units selected from the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 445L	Introduction to Robotics	4
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2
CSCI 485	File and Database Management	3
CSCI 499	Special Topics	2-4
Total units		30
Electrical Engineering (6 units)		
EE 101	Introduction to Digital Logic	3
Technical electives++ (at least four courses for a minimum of 14 units)		14
Free electives		10
Total units		128
Composition/Writing requirement (7 units)		**units**
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340*	Advanced Writing	3
General Education (20 units)		**Units**
General education+		20
pre-Major requirements (17-18 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
Linear Algebra (3-4 units)		
MATH 225	Linear Algebra and Linear Differential Equations, or	4
EE 241	Applied Linear Algebra for Engineering	3
Physics (4 units)		
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics, or	4
PHYS 161L	Advanced Principles of Physics	4
MAJOR REQUIREMENTS (84 UNITS)		**units**
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 350	Introduction to Operating Systems	4
CSCI 353	Introduction to Internetworking	4
CSCI 360	Introduction to Artificial Intelligence	4
CSCI 420	Computer Graphics	4

CSCI 423	Native Console Multiplayer Game Development	4
CSCI 425	Immersive Game Design	4
EE 352L	Computer Organization and Architecture	4
Game Development (31 UNITS)		**units**
CTIN 190	Introduction to Interactive Entertainment	4
CSCI 281	Pipelines for Games and Interactives	3
CSCI 491abL	Final Game Project (4-2)	6
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
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4
Total units		128-129
COMPOSITION/WRITING REQUIREMENT (7 UNITS)		**UNITS**
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
general education (20 UNITS)		**UNITS**
General education		20
Pre-Major requirements (14 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
*Basic Science (4 units)**		
PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics, or	
PHYS 161L	Advanced Principles of Physics, or	4
BISC 120L	General Biology: Organismal Biology and Evolution, or	
BISC 121L	Advanced General Biology: Organismal Biology and Evolution, or	4
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Major Requirements (88-90 units)		**Units**
Statistics and Probability (3-4 units)		
BUAD 310	Applied Business Statistics (4), or	
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science (3), or	
MATH 407	Probability Theory (4)	3-4
Linear Algebra (3-4 units)		
EE 241	Applied Linear Algebra for Engineering (3), or	
MATH 225	Linear Algebra and Linear Differential Equations (4)	3-4
Computer Science Requirements (30 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 310	Introduction to Software Engineering	4
CSCI 477ab	Design and Construction of Large Software Systems (2-2)	4
Computer Science Electives (8 units minimum)		

Take one of the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 360L	Introduction to Artificial Intelligence	4
CSCI 430	Security Systems	4
CSCI 485	File and Database Management	3
And take one approved Computer Science elective (see adviser)		4
Business Requirements (36 units)		
ACCT 410x	Accounting for Non-Business Majors	4
BUAD 302	Communication Strategy in Business	4
BUAD 304	Organizational Behavior and Leadership	4
BUAD 306	Business Finance	4
BUAD 307	Marketing Fundamentals	4
BUAD 311	Operations Management	4
BUAD 497	Strategic Management	4
ECON 351x	Microeconomics for Business	4
ECON 352x	Macroeconomics for Business	4
Business Electives (8 units)		
Take two of the following courses:		
BAEP 452	Feasibility Analysis	4
BAEP 453	Venture Management	4
BUAD 301	Technical Entrepreneurship	3
DSO 431	Managing the Digital Revolution for Your Business	4
DSO 433	Business Information Systems Analysis and Design	4
DSO 443	The Business of Interactive Digital Media	4
DSO 462	Managing a Small Business on the Internet	4
MKT 425	Marketing on the Internet	4
Total units		129-131
Required Courses		**units**
Lower division (18 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development (3), or	
CSCI 270	Introduction to Algorithms and Theory of Computing (4)	3-4
Electives		**units**
12 units selected from the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 445L	Introduction to Robotics	4
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2
CSCI 485	File and Database Management	3
CSCI 499	Special Topics	2-4
Total units		30
Technical electives++ (at least four courses for a minimum of 14 units)		14
Free electives		10

*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 adviser 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.

++ Applicable courses include: CSCI 300, CSCI 351, CSCI 352, CSCI 353, CSCI 420, CSCI 445L, CSCI 459, CSCI 464, CSCI 485, CSCI 490x, CSCI 499; EE 450, EE 454L, EE 459L, EE 465, EE 477L, EE 490x, EE 499; MATH 458. Students may also choose one adviser-approved course from the 300- and 400-level ITP offerings. Other courses may be applicable; please see an adviser for approval.

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.

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 all upper-division courses applied toward the major, regardless of the department in which the courses are taken.

Composition/Writing requirement (7 units)		units
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340*	Advanced Writing	3
General Education (20 units)		Units
General education+		20
pre-Major requirements (17-18 units)		units
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
Linear Algebra (3-4 units)		
MATH 225	Linear Algebra and Linear Differential Equations, or	4
EE 241	Applied Linear Algebra for Engineering	3
Physics (4 units)		
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics, or	4
PHYS 161L	Advanced Principles of Physics	4
MAJOR REQUIREMENTS (84 UNITS)		units
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 350	Introduction to Operating Systems	4
CSCI 353	Introduction to Internetworking	4

CSCI 360	Introduction to Artificial Intelligence	4
CSCI 420	Computer Graphics	4
CSCI 423	Native Console Multiplayer Game Development	4
CSCI 425	Immersive Game Design	4
EE 352L	Computer Organization and Architecture	4
Game Development (31 UNITS)		**units**
CTIN 190	Introduction to Interactive Entertainment	4
CSCI 281	Pipelines for Games and Interactives	3
CSCI 491abL	Final Game Project (4-2)	6
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
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4
Total units		128-129

COMPOSITION/WRITING REQUIREMENT (7 UNITS)		**UNITS**
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
general education (20 UNITS)		**UNITS**
General education		20
Pre-Major requirements (14 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
Basic Science (4 units)*		
PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics, or	
PHYS 161L	Advanced Principles of Physics, or	4
BISC 120L	General Biology: Organismal Biology and Evolution, or	
BISC 121L	Advanced General Biology: Organismal Biology and Evolution, or	4
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Major Requirements (88-90 units)		**Units**
Statistics and Probability (3-4 units)		
BUAD 310	Applied Business Statistics (4), or	
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science (3), or	
MATH 407	Probability Theory (4)	3-4
Linear Algebra (3-4 units)		
EE 241	Applied Linear Algebra for Engineering (3), or	
MATH 225	Linear Algebra and Linear Differential Equations (4)	3-4
Computer Science Requirements (30 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 310	Introduction to Software Engineering	4
CSCI 477ab	Design and Construction of Large Software Systems (2-2)	4
Computer Science Electives (8 units minimum)		

Take one of the following courses:

CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 360L	Introduction to Artificial Intelligence	4
CSCI 430	Security Systems	4
CSCI 485	File and Database Management	3
And take one approved Computer Science elective (see adviser)		4
Business Requirements (36 units)		
ACCT 410x	Accounting for Non-Business Majors	4
BUAD 302	Communication Strategy in Business	4
BUAD 304	Organizational Behavior and Leadership	4
BUAD 306	Business Finance	4
BUAD 307	Marketing Fundamentals	4
BUAD 311	Operations Management	4
BUAD 497	Strategic Management	4
ECON 351x	Microeconomics for Business	4
ECON 352x	Macroeconomics for Business	4
Business Electives (8 units)		

Take two of the following courses:

BAEP 452	Feasibility Analysis	4
BAEP 453	Venture Management	4
BUAD 301	Technical Entrepreneurship	3
DSO 431	Managing the Digital Revolution for Your Business	4
DSO 433	Business Information Systems Analysis and Design	4
DSO 443	The Business of Interactive Digital Media	4
DSO 462	Managing a Small Business on the Internet	4
MKT 425	Marketing on the Internet	4
Total units		129-131

Required Courses		**units**
Lower division (18 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development (3), or	
CSCI 270	Introduction to Algorithms and Theory of Computing (4)	3-4
Electives		**units**
12 units selected from the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 445L	Introduction to Robotics	4
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2
CSCI 485	File and Database Management	3
CSCI 499	Special Topics	2-4
Total units		30
Linear Algebra (3-4 units)		
MATH 225	Linear Algebra and Linear Differential Equations, or	4
EE 241	Applied Linear Algebra for Engineering	3
Physics (4 units)		
PHYS 151L*	Fundamentals of Physics I: Mechanics and Thermodynamics, or	4
PHYS 161L	Advanced Principles of Physics	4
MAJOR REQUIREMENTS (84 UNITS)		**units**
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software	4

	Development	
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 350	Introduction to Operating Systems	4
CSCI 353	Introduction to Internetworking	4
CSCI 360	Introduction to Artificial Intelligence	4
CSCI 420	Computer Graphics	4
CSCI 423	Native Console Multiplayer Game Development	4
CSCI 425	Immersive Game Design	4
EE 352L	Computer Organization and Architecture	4
Game Development (31 UNITS)		**units**
CTIN 190	Introduction to Interactive Entertainment	4
CSCI 281	Pipelines for Games and Interactives	3
CSCI 491abL	Final Game Project (4-2)	6
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
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4
Total units		128-129

* Satisfies GE requirement.

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. The degree is administered by the Computer Science Department.

The minimum 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 all upper division courses applied toward the major, regardless of the department in which the courses are taken.

COMPOSITION/WRITING REQUIREMENT (7 UNITS)		**UNITS**
WRIT 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
general education (20 UNITS)		**UNITS**
General education		20
Pre-Major requirements (14 units)		**units**
Engineering (2 units)		
ENGR 102	Engineering Freshman Academy	2
Mathematics (8 units)		
MATH 125	Calculus I	4
MATH 126	Calculus II	4
Basic Science (4 units)*		
PHYS 151L	Fundamentals of Physics I: Mechanics and Thermodynamics, or	
PHYS 161L	Advanced Principles of Physics, or	4
BISC 120L	General Biology: Organismal Biology and Evolution, or	
BISC 121L	Advanced General Biology: Organismal Biology and Evolution, or	4
CHEM 105aL	General Chemistry, or	
CHEM 115aL	Advanced General Chemistry	4
Major Requirements (88-90 units)		**Units**
Statistics and Probability (3-4 units)		
BUAD 310	Applied Business Statistics (4),	

	or	
EE 364	Introduction to Probability and Statistics for Electrical Engineering and Computer Science (3), or	
MATH 407	Probability Theory (4)	3-4
Linear Algebra (3-4 units)		
EE 241	Applied Linear Algebra for Engineering (3), or	
MATH 225	Linear Algebra and Linear Differential Equations (4)	3-4
Computer Science Requirements (30 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development	4
CSCI 270	Introduction to Algorithms and Theory of Computing	4
CSCI 310	Introduction to Software Engineering	4
CSCI 477ab	Design and Construction of Large Software Systems (2-2)	4
Computer Science Electives (8 units minimum)		
Take one of the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 360L	Introduction to Artificial Intelligence	4
CSCI 430	Security Systems	4
CSCI 485	File and Database Management	3
And take one approved Computer Science elective (see adviser)		4
Business Requirements (36 units)		
ACCT 410x	Accounting for Non-Business Majors	4
BUAD 302	Communication Strategy in Business	4
BUAD 304	Organizational Behavior and Leadership	4
BUAD 306	Business Finance	4
BUAD 307	Marketing Fundamentals	4
BUAD 311	Operations Management	4
BUAD 497	Strategic Management	4
ECON 351x	Microeconomics for Business	4
ECON 352x	Macroeconomics for Business	4
Business Electives (8 units)		
Take two of the following courses:		
BAEP 452	Feasibility Analysis	4
BAEP 453	Venture Management	4
BUAD 301	Technical Entrepreneurship	3
DSO 431	Managing the Digital Revolution for Your Business	4
DSO 433	Business Information Systems Analysis and Design	4
DSO 443	The Business of Interactive Digital Media	4
DSO 462	Managing a Small Business on the Internet	4
MKT 425	Marketing on the Internet	4
Total units		129-131

* Satisfies GE requirement.

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 for course requirements.

Bachelor of Science in Computer Engineering and Computer Science

See the listing under Computer Engineering.

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		**units**
Lower division (18 units)		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object-Oriented Design	4
CSCI 109	Introduction to Computing	3
CSCI 170	Discrete Methods in Computer Science	4
CSCI 201L	Principles of Software Development (3), or	
CSCI 270	Introduction to Algorithms and Theory of Computing (4)	3-4
Electives		**units**
12 units selected from the following courses:		
CSCI 351	Programming and Multimedia on the World Wide Web	3
CSCI 445L	Introduction to Robotics	4
CSCI 460	Introduction to Artificial Intelligence	3
CSCI 477ab	Design and Construction of Large Software Systems	2-2
CSCI 485	File and Database Management	3
CSCI 499	Special Topics	2-4
Total units		30

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 USC Roski School of Art and Design.

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 USC Roski School of Art and Design.

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. 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.

A Master of Science in Computer Science (High Performance Computing and Simulations) is also offered.

A Master of Science in Computer Science (Data Science) is also offered.

A Master of Science in Computer Science (Game Development) is also offered.

A Master of Science in Computer Science (Computer Security) is also offered.

A Master of Science in Computer Science (Technical Professionals) is also offered for students with three to five years of work experience.

A Master of Science in Computer Science (Scientists and Engineers) is also offered for students with limited background in computer science.

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 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 (TOEFL) or International English Language Testing System (IELTS).

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 4 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.

A maximum of 4 units may be taken at the 400 level from approved courses in either electrical engineering or computer science; the specialization "Game Development"; allows for up to 7 units at the 400 level. The remaining units must be approved courses at the 500 or 600 level.

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 4 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 594abz 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 (Data Science)

The Master of Science in Computer Science (Data Science) provides students with a core background in computer science and specialized algorithmic, statistical and systems expertise in acquiring, storing, accessing, analyzing and visualizing large, heterogeneous and real-time data associated with diverse real-world domains including energy, the environment, health, media, medicine and transportation. Students must satisfy all the requirements for the Master of Science degree in Computer Science. The following additional requirements must be met to obtain an M.S. in Computer Science with a specialization in Data Science.

Required Courses		units
CSCI 561	Artificial Intelligence	3
CSCI 570	Analysis of Algorithms	3
CSCI 585	Database Systems	3
EE 517	Statistics for Engineers	3
Group Electives (must take 3 courses with a minimum of 1 course from each group):		**units**
Group 1 (Data Systems):		
CSCI 548	Information Integration on the Web	3
CSCI 572	Information Retrieval and Web Search Engines	3
CSCI 586	Database Systems Interoperability	3
CSCI 587	Geospatial Information Management	3
CSCI 653	High Performance Computing and Simulations	3
CSCI 685	Advanced Topics in Database Systems	3
Group 2 (Data Analysis):		
CSCI 567	Machine Learning	3
CSCI 573	Probabilistic Reasoning	3
CSCI 686	Advanced Big Data Analytics	3
ISE 520	Optimization: Theory and Algorithms	3
MATH 467	Theory and Computational Methods for Optimization	4
MATH 574	Applied Matrix Analysis	3
Electives (a minimum of 2 courses)		**units**

Any 500- or 600-level course in CSCI (including additional group electives)		
MATH 458	Numerical Methods	4
MATH 501	Numerical Analysis and Computation	3
MATH 502ab	Numerical Analysis	3-3
MATH 505a	Applied Probability	3
MATH 601	Optimization Theory and Techniques	3
MATH 650	Seminar in Statistical Consulting	3

Total units required for the degree is 27. No more than 4 units may be taken at the 400-level.

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	Probabilistic Reasoning	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**
CSCI 522	Game Engine Development	4
CTIN 488	Game Design Workshop	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	Probabilistic Reasoning	3
Immersion		
CSCI 520	Computer Animation and Simulation	3
CSCI 523	Networked Games	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 520	Computer Animation and Simulation	3
CSCI 537	Immersive Environments	3
CSCI 538	Human Performance Engineering	3
Other courses may be eligible subject to adviser 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 adviser. All courses must be approved by a faculty adviser. 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*	Probabilistic Reasoning	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
CSCI 558L	Internetworking and Distributed Systems Laboratory	3
CSCI 571	Web Technologies	3
CSCI 585	Database Systems	3
CSCI 599**	Special Topics	2-4, max 9
CSCI 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 adviser. 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
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	
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	Basics of Atomistic Simulations of	3

575*	Materials	
MATH 578a	Computational Molecular Biology	3
PHYS 516	Methods of Computational Physics	3
PTE 582*	Fluid Flow and Transport Processes in Porous Media	3
Adviser approved remainder of elective units		6

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

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 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	Probabilistic Reasoning	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

* Also satisfies a core course requirement in the general requirements for the M.S. degree in Computer Science.

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.

Master of Science in Computer Science (Intelligent Robotics)

Students must take CSCI 545 and three of the following courses: CSCI 445L, CSCI 547 and CSCI 584. 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.

Master of Science in Computer Science (Scientists and Engineers)

Designed for students with engineering or science bachelor's degree but limited background in computer science, this comprehensive, two-year, 37-unit program combines an introductory sequence of undergraduate preparatory and foundational course work with all the graduate breadth requirements necessary to satisfy the traditional master's degree. Applicants to this program must meet the admissions standards of the Viterbi School of Engineering.

Preparatory Programming Requirement		units
CSCI 455x*	Introduction to Programming Systems Design	4
Foundational Requirements		**units**
CSCI 402	Operating Systems	4
EE 457	Computer Systems Organization, or	
EE 450	Introduction to Computer Networks	3
Breadth Requirements		**units**
CSCI 561	Foundations of Artificial Intelligence	3
CSCI 570	Analysis of Algorithms	3
CSCI 577ab	Software Engineering	4-4
CSCI 585	Database Systems	3
Electives		

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 103L Introduction to Programming (3, FaSp) *Basic datatypes, assignments, control statements (if, switch, for, while), input/output (printf, scanf, cin, cout), functions, arrays, structures, recursion, dynamic memory, file handling. Programming in C/C++. Corequisite:* CSCI 109 or EE 109.

CSCI 104L Data Structures and Object Oriented Design (4, FaSp) *Introduces the student to standard data structures (linear structures such as linked lists, (balanced) trees, priority queues, and hashtables),*

using the C++ programming language. Prerequisite: CSCI 103L; corequisite: CSCI 170.

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

CSCI 109 Introduction to Computing (3, FaSp) Computing as a discipline, a body of knowledge, and a domain of science/engineering concerned with information and its transformation.

CSCI 110 Introduction to Digital Logic (3) (Enroll in EE 101)

CSCI 170 Discrete Methods in Computer Science (4, FaSp) *Sets, functions, series. Big-O notation and algorithm analysis. Propositional and first-order logic. Counting and discrete probability. Graphs and basic graph algorithms. Basic number theory. (Duplicates credit in CSCI 271.) Prerequisite: CSCI 103L and CSCI 109.*

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 201L Principles of Software Development (4, FaSp) *Object-oriented paradigm for programming-in-the-large in Java; writing sophisticated concurrent applications with animation and graphic user interfaces; using professional tools on team project. Prerequisite: CSCI 104L.*

CSCI 270 Introduction to Algorithms and Theory of Computing (4, FaSp) *Algorithm analysis. Greedy algorithms, divide and conquer, dynamic programming, graph algorithms. NP-completeness and basic recursion theory and undecidability. Sorting lower bounds. Number-theory based cryptography. (Duplicates credit in CSCI 303.) Prerequisite: CSCI 104L and CSCI 170.*

CSCI 280 Video Game Production (4, FaSpSm) (Enroll in ITP 280)

CSCI 281 Pipelines for Games and Interactives (3, FaSp) 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 or CSCI 103.*

CSCI 310 Software Engineering (4, Sp) *Introduction to the software engineering process and software lifecycle. Covers project management, requirements, architecture, design, implementation, testing, and maintenance phase activities in team based projects. Prerequisite: CSCI 201L. (Duplicates credit in CSCI 377.)*

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

CSCI 350 Introduction to Operating Systems (4) *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 and EE 352. (Duplicates credit in CSCI 402.)*

CSCI 351 Programming and Multimedia on the World Wide Web (3, FaSpSm) *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 104.

CSCI 352L Computer Organization and Architecture (3, Sp) *(Enroll in EE 352L)*

CSCI 353 Introduction to Internetworking (4) *Global Internet: design principles, layering, protocol design/analysis. Networked applications, Internet structure/architecture, Protocols for transport/congestion control, network layer/routing, link layer/MAC. Network security. Prerequisite: CSCI 201; recommended preparation: Familiarity with C and C++. (Duplicates credit in EE 450.)*

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

CSCI 360L Introduction to Artificial Intelligence (4) *Concepts and algorithms underlying the understanding and construction of intelligent systems. Agents, problem solving, search, representation, reasoning, planning, machine learning. Prerequisite: CSCI 104L and CSCI 170. (Duplicates credit in CSCI 460.)*

CSCI 377 Introduction to Software Engineering (3) *Introduction of principles, methods, techniques, and tools for multi-person construction of multi-version software systems. Prerequisite: CSCI 104.*

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 (4, FaSpSm) *Concurrency, deadlock control, synchronization, process and thread scheduling, memory management, file systems, security and access control, communication and networking, distributed file systems, data management. Prerequisite: CSCI 201L or CSCI 455x; EE 352L or EE 357.*

CSCI 410x Translation of Programming Languages (3) *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 420 Computer Graphics (4, FaSp) *Computer graphics, OpenGL, 2D and 3D transformations, Bézier splines, computer animation, rendering including ray tracing, shading and lighting, artistic rendering, virtual reality, visualization. Prerequisite: CSCI 104L and MATH 225.*

CSCI 423 Native Console Multiplayer Game Development (4) *Implementation of AAA style multiplayer game running on consoles and DX11. Console development in native C++, console SDKs, engine components, gameplay, networking, data prediction/replication. Prerequisite: CSCI 522 or ITP 380; recommended preparation: ITP 485.*

CSCI 424 Game Engine Tool Development (4) *Tool development for a C++ console game. Animation export, compression. FBX parsing. Level editing, object live update tools. Debugging tools. Texture compression. Data Pipeline. Prerequisite: ITP 380; recommended preparation: ITP 485.*

CSCI 425 Immersive Game Development (4) *Implementation of a console multiplayer game leveraging input devices such as Kinect, PSMove, Console + IPad/PSVita, Cloud Computing, to achieve creative design. Prerequisite: CSCI 423.*

CSCI 430 Introduction to Computer and Network Security (4, Sp) *A broad overview of security threats and defenses, security systems and functionalities, as well as current security practices. Includes homeworks and in-class exercises to provide practical experience working with such systems.* Prerequisite: CSCI 201.

CSCI 445L Introduction to Robotics (4, FaSpSm) *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 103.

CSCI 450 Introduction to Computer Networks (3) (Enroll in EE 450)

CSCI 452 Parallel and Distributed Computation (3) (Enroll in EE 451)

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.* Prerequisite: CSCI 104.

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 476 Cryptography: Secure Communication and Computation (4) *Introduction to modern Cryptography; mathematical/algorithmic studies of methods for protecting information in computer and communication systems: Public-Key Cryptosystems, zero-knowledge proofs, data privacy.* Prerequisite: CSCI 270.

CSCI 477ab Design and Construction of Large Software Systems (2-2, FaSpSm) *Programming methodologies; intra-group and inter-group communication; software life-cycle; software economics. A large software project is a central aspect of the course.* Prerequisite: CSCI 201. Open only to seniors.

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 487 Programming Game Engines (4, FaSp) (Enroll in ITP 485)

CSCI 490x Directed Research (1-8, max 12) Individual research and readings. Not available for graduate credit.

CSCI 491abL Final Game Project (4-2, FaSpSm) *a:* Design, iterative prototyping, and development of a 1st playable level. Open only to seniors. *b:* Design, iterative stage 2 prototyping and development of a refined game.

CSCI 492 Immersive Game Development (2, Sp) *Design/develop 3D immersive games using advanced input devices, including sensors, video cameras, Wii-motes, accelerometer-inertial-magnetic sensor combinations, Microsoft Kinect systems, Sony Move, etc. Recommended preparation:* CTIN 488, CSCI 480, and significant participation in a prior game development effort.

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) *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 104 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) *Fundamental techniques of computer animation and simulation, knowledge and/or experience in the design, scripting, production and post-production stages of computer animation. Recommended preparation:* CSCI 420 or equivalent.

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, FaSpSm) *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 420 or CSCI 580 or an equivalent course in graphics.

CSCI 524 Networked Artificial Intelligence (3, FaSpSm) *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 420 or CSCI 580 or an equivalent course in graphics.

CSCI 525 Advanced Game System Development (2, Sp) *Topics include: game engine/tool development, AI/autonomous character integration, game networking, performance measurement/enhancement, character animation systems, mobile devices, game consoles, next generation gameplay.* Prerequisite: CSCI 522 or CSCI 523 or CSCI 524 or CSCI 526 or CSCI 529b; *recommended preparation:* significant participation in a prior game development effort.

CSCI 526 Advanced Mobile Devices and Game Consoles (3, FaSpSm) *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 420 or 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 402.

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 540 Self-Organization (3) *Massively distributed systems whose global behavior emerges from local interactions of components. Global to local compilation; robot swarms; formation of shapes/spatial patterns; self-assembly; programmable matter. Recommended preparation:* Graduate standing in science or engineering.

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 Applied Natural Language Processing (3, Sp) *Introduction to key components of human language technologies, including: information extraction, sentiment analysis, question answering, machine translation. Recommended preparation:* proficiency in programming, algorithms and data structures, basic knowledge of linear algebra.

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 550 Advanced Data Stores (3) *Selected topics on highly available, elastic data stores. Topics include non-relational data models, simple interfaces and query languages, weak consistency and benchmarking techniques. Prerequisite:* CSCI 485 or CSCI 585.

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) (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 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 567 Machine Learning (3, Fa) *Statistical methods for building intelligent and adaptive systems that improve performance from experiences; focus on theoretical understanding of these methods and their computational implications. Recommended preparation:* Undergraduate level training or course work in linear algebra, multivariate calculus, basic probability and statistics; an undergraduate level course in Artificial Intelligence may be helpful but is not required.

CSCI 568 Requirements Engineering (3, Fa) Techniques for successful requirements analysis and requirements engineering (RE) of software-intensive systems. Systematic process of developing requirements through cooperative problem analysis, representation, and validation.

CSCI 570 Analysis of Algorithms (3, FaSpSm) 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, FaSpSm) *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 Probabilistic Reasoning (3, Fa) *Reasoning under uncertainty, statistical directed and undirected graphical models, temporal modeling, inference in graphical models, parameter learning, decisions under uncertainty. Recommended preparation:* An undergraduate level course in probability theory.

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, Fa) 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 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 445L or CSCI 460 or CSCI 547 or CSCI 561.

CSCI 585 Database Systems (3, FaSpSm) 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.

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 587 Geospatial Information Management (3, Fa) *Techniques to efficiently store, manipulate, index and query geospatial information in support of real-world geographical and decision-making applications. Prerequisite:* CSCI 485 or 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 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 Low-Power Wireless Networks (3, Fa) (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 662 Advanced Natural Language Processing (3, Fa) *Computational models of natural language. Formalisms for describing structures of human language, and algorithms for learning language structures from data. (Duplicates credit in former CSCI 562.) Recommended preparation:* proficiency in programming, algorithms and data structures, discrete math, probability theory, and calculus.

CSCI 664 From Action to Language (3, Sp) *Analysis of neurocomputational processes linking action, perception, emotion and language within an evolutionary framework integrating data from neuroscience, primatology, human psychology and linguistics. Recommended preparation:* graduate standing with background or strong interest in one of linguistics, computational neuroscience (e.g., CSCI 564), robotics, or emotion.

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 671 Randomized Algorithms (3, Sp) *Standard techniques in the design and analysis of randomized algorithms and random structures. Topics include tail bounds, Markov Chains, VC-dimension, probabilistic method. Prerequisite: CSCI 570 or CSCI 670; recommended preparation:* basic background in probability.

CSCI 672 Approximation Algorithms (3, Sp) *Algorithmic techniques include combinatorial algorithms and rounding of linear and semi-definite programs. Applications include network design, graph cuts, covering problems, and approximation hardness. Prerequisite: CSCI 570 or CSCI 670; recommended preparation:* basic background in probability and linear algebra.

CSCI 673 Structure and Dynamics of Networked Information (3, Sp) *Algorithms for analyzing network data and spreading information over networks. Focuses on broadly applicable mathematical tools and techniques, including spectral techniques, approximation algorithms and randomization. Prerequisite: CSCI 570 or CSCI 670; recommended preparation:* basic background in probabilities, linear algebra.

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 Convex and Combinatorial Optimization (3) *Topics include: Convex sets and functions; convex optimization problems; geometric and Lagrangian duality; simplex algorithm; ellipsoid algorithm and its implications; matroid theory; submodular optimization. Prerequisite: CSCI 570 or CSCI 670; recommended preparation:* Mathematical maturity and a solid grounding in linear algebra.

CSCI 676 Multimodal Probabilistic Learning of Human Communication (3, Fa) *Computational models of human communicative behaviors. Linguistic, acoustic and visual modalities during social interaction. Multimodal machine learning and pattern recognition, including generative and discriminative models. Recommended preparation:* CSCI 542 or CSCI 567 or CSCI 573 or equivalent; proper academic background in probability, statistics and linear algebra; previous experience in machine learning is suggested but not obligatory. This course is not a replacement for CSCI 567.

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 686 Advanced Big Data Analytics (3) *Advanced statistical inference and data mining techniques for data analytics, including: topic modeling, structure learning, time-series analysis, learning with less supervision, and massive-scale data analytics. Recommended preparation:* CSCI 567, CSCI 573 or EE 559.

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.

Ming Hsieh Department of Electrical Engineering

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Associate Chair (Systems): Bhaskar Krishnamachari, Ph.D.

Associate Chair (Curriculum and Student Services): Edward W. Maby, Ph.D.

Faculty

Presidential Chair: Andrew J. Viterbi, Ph.D.

Presidential Chair: Simon Ramo, Ph.D.

Kenneth C. Dahlberg Early Career Chair: Rahul Jain, Ph.D.

Lloyd F. Hunt Chair in Electrical Power Engineering: Martin Gundersen, Ph.D.

William M. Keck Chair in Engineering: P. Daniel Dapkus, Ph.D.

Robert G. and Mary G. Lane Early Career Chair: Murali Annavaram, Ph.D.

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

Robert C. Packard President's Chair and Malcolm R. Currie Chair in Technology and the Humanities: C. L. Max Nikias, Ph.D.

Colleen and Roberto Padovani Early Career Chair in Electrical Engineering: Mike Chen, Ph.D.

George T. Pfleger Chair in Electrical Engineering: Robert W. Hellwarth, Ph.D.

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

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

Degree Requirements

Undergraduate Program Educational 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.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Electrical Engineering provides both breadth and depth across the range of engineering topics implied by the title. The curriculum includes probability and statistics, including appropriate applications; mathematics through differential and integral calculus, and advanced mathematics, such as differential equations, linear algebra, complex variables and discrete mathematics; sciences (defined as biological, chemical or physical science); and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software and systems containing hardware and software components.

Bachelor of Science in Electrical Engineering

The requirement for the degree is 131 units. A cumulative grade point average of C (2.0) is required for all courses taken at USC as well as all upper division courses applied towards the major, regardless of the department in which the courses are taken. See also the common requirements for undergraduate degrees section.

composition/writing requirements		Units
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	43
General Education		**Units**

pre-major requirements		Units
General education* +		20
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
MATH 445	Mathematics of Physics and Engineering II	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**
Engineering		
ENGR 102	Engineering Freshman Academy	2
Computer Science		
EE 355x	Software Design for Engineers	3
Electrical Engineering		
EE 109L	Introduction to Embedded Systems	3
EE 105	Introduction to Electrical Engineering	3
EE 150L	Engineering Computational Methods	3
EE 202L	Linear Circuits	4
EE 301L	Linear Systems	4
EE 330	Electromagnetics I	3
EE 364***	Introduction to Probability and Statistics for Electrical Engineering and Computer Science	
Industrial and Systems Engineering		
ISE 460	Engineering Economy, or	
BUAD 301	Technical Entrepreneurship	3
Major electives		**Units**
Electives	See requirements for graduation	37
Total units:		131

* GE Category VI is taken concurrently with WRIT 150.

** Satisfies GE Category III requirement.

*** Students enrolled in the progressive degree program may take EE 503 (4) to satisfy this requirement

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

Requirements for Graduation: Engineering Electives

Entry-Level Electives

Students are required to take four entry-level electives from the following list: EE 241 (3), EE 322 (3), EE 337L (3), EE 338 (3), EE 348L (4), EE 357 (3).

Advanced Electives

Students must fulfill a minimum requirement of three 400-level elective courses in electrical engineering. Of these, one must be a capstone design course from the following list: EE 422x (3), EE 423x (3), EE 434Lx (4), EE 447Lx (4), EE 459x (3), EE 484x (3).

Free Electives

Free elective courses that complete the 37-unit elective requirement are to be chosen in consultation with the student's academic adviser. Students are encouraged to pursue minor options when satisfying this requirement.

Bachelor of Science in Computer Engineering and Computer Science

See the listing under Computer Engineering.

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.

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 adviser 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 adviser-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 adviser 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 adviser 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 three of the four following fundamental courses: CSCI 402x, EE 450, EE 457Lx, and EE 465 or EE 503. With the exception of EE 503, the fundamental courses may also be satisfied by having passed EE placement exams. Three of the following courses are required: CSCI 551, EE 550, EE 555 and EE 597. If a fourth required course is taken it can be counted toward elective credit. Suggested elective courses include: CSCI 530, CSCI 555, CSCI 558L, CSCI 570, CSCI 694a, CSCI 694b, EE 512, EE 532, EE 535, EEE 549, E 554, EE 557, EE 558, EE 579, EE 590, EE 649, EE 650, EE 652, EE 659. Any other course must be approved by a faculty adviser. Total units required for the degree is 27.

Master of Science in Electrical Engineering (Electric Power)

See listing in the Sustainable Infrastructures Systems section.

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:

- At most four units of electives can be taken outside of the Viterbi School of Engineering with adviser approval. Some examples are CTAN 452 Introduction to 3-D Computer Animation (2 units) and CTIN 483 Introduction to Game Development (4 units).

- 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.

- Students must include the following three courses in their program

EE 483	Introduction to Digital Signal Processing	3
EE 519	Speech Recognition and Processing for Multimedia	3
EE 569	Introduction to Digital Image Processing	3

- A course can be waived if a student can demonstrate equivalent knowledge of the material and if the course instructor will certify it.

- Students must include six courses from the following list of courses in their programs for a total of 18 units.

Approved Courses for the Multimedia Specialization

Courses in Electrical Engineering		**units**
EE 450	Introduction to Computer Networks	3
EE 522	Immersive Audio Signal Processing	3
EE 555	Broadband Network Architectures	3
EE 577a	VLSI System Design	3
EE 586L	Advanced DSP Design Laboratory	4
EE 596	Wavelets	3
EE 619	Advanced Topics in Automatic Speech Recognition	3
EE 669	Multimedia Data Compression	3
Courses in Computer Science		**Units**
CSCI 455x	Introduction to Programming Systems Design	4
CSCI 485	File and Database Management	3
CSCI 551	Computer Communications	3

CSCI 571	Web Technologies	3
CSCI 574	Computer Vision	3
CSCI 576	Multimedia Systems Design	3
CSCI 580	3-D Graphics and Rendering	3
CSCI 582	Geometric Modeling	3
CSCI 585	Database Systems	3
Courses from the School of Cinematic Arts		**Units**
CTAN 452	Introduction to 3-D Computer Animation	2, max 4
CTIN 483	Introduction to Game Development	4
Course in Information Technology		**Units**
ITP 411x	Multimedia and Video Production	3

- Students may replace courses in the above list with a combined maximum of multimedia-related EE 599 or CSCI 599 Special Topics courses in their programs. Every course requires prior approval from the faculty adviser, recorded each semester on the plan of study form.

- Students may include a maximum of 6 units of EE 590 Directed Research in their programs. Before registering for these units, the faculty adviser must approve a written description of the intended multimedia research project signed by the faculty member who will supervise the student.

- 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. If an approved course has either EE 441 or EE 464 as a prerequisite, then the student must first take and pass the placement examination that is given each semester for either EE 441 or EE 464 before taking the approved course. Information about placement exams can be found at ee.usc.edu.

- Although not required, students should be proficient in C or C++ programming, at the level taught in CSCI 455x.

- Although not required, ITP 411x Multimedia and Video 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 the industry from students who major in a multimedia program.

Master of Science in Systems Architecting and Engineering

See the listing under Systems Architecting and Engineering.

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 adviser-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 adviser, 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 adviser, and can including the following: EE 501, EE 502, EE 504L, EE 506, EE 540, EE 554, EE 560, EE 590, EE 601 and EE 677.

Master of Science in Electrical Engineering (Wireless Health Technology)

The Master of Science in Electrical Engineering (Wireless Health Technology) reflects a partnership between the Viterbi School of Engineering, the Keck School of Medicine, and other institutions engaged in health care research. The program of study features targeted engineering courses, a rigorous exposure to general medicine, and relevant internship practice (a total of 29-32 units).

Required Courses (20 units)		units
EE 450	Introduction to Computer Networks	3
EE 579	Wireless and Mobile Networks Design and Laboratory	3
MEDS 530abc	Foundations of Medicine, Anatomy, Physiology, and Pathology	12
MEDS 597ab	Health Technology Internship	1-1
Take three electives from the following list (9-12 units)		
CSCI 545	Robotics	3
CSCI 561	Foundations of Artificial Intelligence	3
EE 503	Probability for Electrical and Computer Engineers	4
EE 519	Speech Recognition and Processing for Multimedia	3
EE 535	Mobile Communications	3
EE 550	Design and Analysis of Computer Communication Networks	3
EE 559	Mathematical Pattern Recognition	3
EE 564	Communication Theory	3
EE 565a	Information Theory	3
EE 567	Communication Systems	3
MEDS 500	Basic Concepts in Global Health	4
MEDS 501	Critical Issues in Global Health	4
MEDS 502	Global Epidemiology of Diseases and Risk Factors	4
Total:		29-32 units

Students are expected to have a background in linear algebra equivalent to EE 441 and experience with a programming language such as C or C++. Admitted students who do not meet prerequisites by placement examination will be assigned courses to complete the deficiencies.

Master of Science in Electrical Engineering (Wireless Networks)

The Master of Science in Electrical Engineering (Wireless Networks) is a unique interdisciplinary degree program that prepares graduates for the design and improvement of future wireless networks such as the "Internet of Things."; The program combines courses related to radio hardware, transmission techniques, the medium-access control layer, networking, applications and standards.

REQUIRED COURSES (15 UNITS)		Units
CSCI 402	Operating Systems	4
EE 503	Probability for Electrical and Computer Engineers	4
EE 511	Simulation Methods for Stochastic Systems	1
EE 535	Mobile Communications	3
EE 597	Wireless Networks	3
ELECTIVE COURSES (12-14 UNITS, AT LEAST ONE COURSE FROM TWO AREAS)		**Units**
Transmission Techniques and Signal Processing		
EE 483	Introduction to Digital Signal Processing	3
EE 558	Optical Fiber Communication Systems	3
EE 564	Communication Theory	3
EE 583	Statistical Signal Processing	3
EE 586L	Advanced DSP Design Laboratory	4
Architectures, Protocols, and Applications		
EE 519	Speech Recognition and Processing for Multimedia	3
EE 532	Wireless Internet and Pervasive Computing	3
EE 550	Design and Analysis of Computer Communication Networks	3
EE 555	Broadband Network Architectures	3
EE 579	Wireless and Mobile Networks Design and Laboratory	3
EE 652	Low-Power Wireless Networks	3
Communication Hardware and Design		
EE 448L	Communication Electronics	4
EE 541	Radio Frequency Filter Design	3
EE 544	Radio Frequency Systems and Hardware	3

Note: This program assumes prerequisite preparation in the area of computer networks. Students who do not meet this requirement or who do not pass a related placement exam will be required to take EE 450 Introduction to Computer Networks.

Financial Engineering

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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 USC Marshall School of Business and the USC Dornsife 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 30 units is required; (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 adviser approval) must have been taken prior to taking classes at USC; interruption of residency is not allowed.

Curriculum

The degree requirements include six required courses and two courses from each of two lists of electives for a minimum total of 30 units.

Required		Units
GSBA 548	Corporate Finance	3
FBE 559	Management of Financial Risk, or	3
ISE 563	Financial Engineering	3
EE 503	Probability for Electrical and Computer Engineers	4
EE 512	Stochastic Processes	3
EE 518	Mathematics and Tools for Financial Engineers	4
EE 590	Directed Research, or	
ENGR 596	Internship in Engineering	1
Electives (adviser approved)		**Units**
Finance, Business, Economics Area:		
Two courses (6-7 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 540	Hedge Funds	3
FBE 543	Forecasting and Risk Analysis	3
FBE 554	Trading and Exchanges	3
FBE 555	Investment Analysis and Portfolio Management	3
FBE 589	Mortgages and Mortgage-Backed Securities and Markets	3
ISE 566	Financial Accounting Analysis for Engineering	3
Optimization, Simulations, Stochastic Systems:		
Two courses (6-7 units) from the following:		
CE 645	Uncertainty Modeling and Stochastic Optimization	3
CSCI 455x	Introduction to Programming Systems Design	4
CSCI 570	Analysis of Algorithms	3
EE 500	Neural and Fuzzy Systems	3
EE 517	Statistics for Engineers	3
EE 553*	Computational Solution of Optimization Problems	3
EE 556	Stochastic Systems	3
EE 562a	Random Processes in Engineering	3
ISE 520*	Optimization: Theory and Algorithms	3
ISE 536	Linear Programming and Extensions	3
ISE 539	Stochastic Elements of Simulation	3

* Students cannot receive credit for both ISE 520 and EE 553

Dual Degree Program (M.S., Electrical Engineering / M.S., Engineering Management)

The Ming Hsieh Department of Electrical Engineering in conjunction with the Daniel J. Epstein Department of Industrial and Systems Engineering offers a program leading to the degree of Master of Science in Electrical Engineering/Master of Science in Engineering Management. This program is designed for graduate electrical engineers whose career objectives lead to increasing technical management responsibilities.

In addition to the general requirements of the USC Viterbi School of Engineering, the dual degree of Master of Science in Electrical Engineering and Master of Science in Engineering Management is also subject to the following requirements:

(1) All applicants must meet the admissions requirements of both the department of electrical engineering and the department of industrial and systems engineering; (2) a total of at least 48 units is required; (3) 24 of these must satisfy the requirements of the master's degree in electrical engineering; (4) 21 units must satisfy the required courses towards the master's degree in engineering management; (5) 3 units of electives approved by the program director or adviser; (6) all courses counted towards the dual degree must be at the 500 level, except those 400-level courses required by the master's degree in electrical engineering.

Second Master's Degree

A graduate student who already holds a master's degree from USC 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.

For students who earned their first master's degree at another institution, no course work may be repeated from the first program of study and no unit credit from the first program of study may be counted toward the second master's degree.

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.

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. (Duplicates credit in EE 154.)

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 109L Introduction to Embedded Systems (3, Fa) *Information representations, embedded C language constructs, assembly programming, state machines, and fundamental circuit analysis. Embedded topics will include digital I/O, serial I/O protocols, analog-to-digital conversion and interrupt mechanisms. Recommended preparation:* Knowledge of C or C++.

EE 150L Engineering Computational Methods (3, Fa) Algorithms and computational methods for efficient solution of engineering problems. Introduction to engineering software tools.

EE 154 Fundamentals of Digital Logic (2) *Logic function synthesis, Boolean algebra, sequential devices, state-machine synthesis, combinational and sequential data-path components. Prerequisite:* EE 109L. (Duplicates credit in EE 101.) Open only to Computer Engineering and Computer Science and Electrical Engineering majors.

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:* MATH 245.

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 254L Introduction to Digital Circuits (4, FaSpSm) *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; semester-end project. Prerequisite:* EE 101 or EE 154. (Duplicates credit in former EE 201.)

EE 277L Introduction to Digital Integrated Circuits (2) *Physical principles and circuit theory used to analyze and design digital integrated circuits.*

Introduction to digital abstractions that bridge the gap between basic circuit theory and VLSI. Prerequisite: EE 109. (Duplicates credit in EE 328.)

EE 301L Linear Systems (4, 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.*

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, FaSpSm) (Enroll in CSCI 351)

EE 352L Computer Organization and Architecture (3) *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 104.*

EE 355x Software Design for Electrical Engineers (3) *Object-oriented programming techniques, basic data structures, and elementary complexity analysis for the modeling, simulation, and solution of engineering problems. Not available for credit for CSCI, CSGM, CSBA, or CECS majors. (Duplicates credit in former CSCI 355x). Prerequisite: EE 150.*

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 254; recommended preparation: 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.*

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 301L 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 301L 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.*

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 microfabrication. (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.

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 445L)

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. (Duplicates credit in CSCI 353.) Prerequisite: junior standing.*

EE 451 Parallel and Distributed Computation (3) *Architectural principles underlying modern processors; introduction to parallel programming techniques, software performance optimization strategies, and application mapping to multi-core, accelerator and cloud platforms. Prerequisite: EE 352; recommended preparation: Knowledge of C/C++.*

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, FaSpSm) *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; hardware/simulation labs. Prerequisite: EE 254L.*

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

EE 457 Computer Systems Organization (3, FaSpSm) *Register Transfer level machine organization; performance; arithmetic; pipelined processors; exceptions, out-of-order and speculative execution, cache, virtual memory, multi-core multi-threaded processors, cache coherence. Prerequisite: EE 254L.*

EE 459Lx Embedded Systems Design Laboratory (3, FaSpSm) *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. Prerequisite: EE 357; recommended preparation: Knowledge of C programming. Open only to seniors.*

EE 460 Introduction to Artificial Intelligence (3) (Enroll in CSCI 460)

EE 464 Probability Theory for Engineers (3, FaSpSm) *Axiomatic foundations of probability, random variables, functions of several random variables, introduction to statistics, sequences of random variables. Prerequisite: EE 301L and MATH 445.*

EE 465 Probabilistic Methods in Computer Systems Modeling (3, FaSp) *Review of probability; random variables; stochastic processes; Markov chains; and simple queueing theory. Applications to program and algorithm analysis; computer systems performance and reliability modeling. Prerequisite:* MATH 407 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 301L.*

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, FaSpSm) *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 277L 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 nanobiotechnology. Prerequisite: EE 338.*

EE 481L Control Systems Laboratory (3, Sp) (Enroll in AME 443L)

EE 482 Linear Control Systems (3, FaSpSm) *Analysis of linear control systems; continuous and sampled-data systems, various stability criteria; frequency response and root locus compensation techniques. Prerequisite: EE 301L 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 301L.*

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 485 Telecommunications Technology (3) *Technical development of the telecommunications industry and the accompanying regulatory environment. Case-study analysis. Prerequisite: EE 301L.*

EE 490x Directed Research (1-8, max 12) 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, FaSpSm) *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 or EE 503.*

EE 501 Solid State (3) (Enroll in MASC 501)

EE 502 Advanced Solid State (3) (Enroll in MASC 502)

EE 503 Probability for Electrical and Computer Engineers (4, FaSp) Rigorous coverage of probability, discrete and continuous random variables, functions of multiple random variables, covariance, correlation, random sequences, Markov chains, estimation, and introduction to statistics. (Duplicates credit in EE 464 and EE 465.)

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.

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.

EE 507 Micro- and Nano-Fabrication Technology (3) *Physical basis of technologies for the fabrication of micro- and nano-scale devices. Thin-film deposition, etching, and material modification processes; pattern-transfer methods. Recommended preparation:* graduate standing in engineering, physics, or chemistry.

EE 508 Nano-Fabrication Lithography (3) Physical basis of lithography methods for nano-scale devices. Photon-, electron-, and ion-based systems,

advanced processes; resolution enhancement techniques; directed self assembly.

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 511 Simulation Methods for Stochastic Systems (1) *Project-oriented investigation of simulation methods used for the analysis and design of complex stochastic systems whose operation and performance are affected by random events. Corequisite: EE 503; recommended preparation:* MatLab programming experience.

EE 512 Stochastic Processes (3) *Probability theory and stochastic processes, including renewal theory, Markov chains, Brownian motion, martingales, and stochastic calculus. Applications in communication networks, queuing theory, and financial systems. Prerequisite: EE 441 and EE 464, EE 465 or EE 503.*

EE 513 Solid State Energy Devices (3) *Design and operation of solar photovoltaic energy converters, thermovoltoic energy converters, thermoelectric energy converters, and solid state light emitters; their roles in renewal and conservation of energy. Recommended preparation: EE 338.*

EE 514 Quantum Error Correction (3) *A comprehensive introduction to quantum error correction and decoherence control, from the basics to the cutting edge, enabling students to delve into current research topics. Recommended preparation: EE 520.*

EE 515 High-Voltage Technology (3) High voltage engineering basic concepts; theoretical, design, and practical aspects of overvoltages, travelling-waves, insulation, and aging; breakdown mechanisms; insulation coordination.

EE 516 High-Voltage DC Transmission Systems (3) *AC/DC conversion processes, converter technologies, and design; harmonics, controls, and protection; AC/DC interactions and system performance; modeling, application, and installation; current-source versus voltage-source converters. Prerequisite: EE 443.*

EE 517 Statistics for Engineers (3, FaSpSm) *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 EE 503.*

EE 518 Mathematics and Tools for Financial Engineering (4) Students will build a mathematical background for studying financial engineering. Emphasis is on analysis, proofs and examples. Mathwork's financial toolbox will be introduced.

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, FaSpSm) *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 and EE 464 or EE 503.*

EE 521 Power Systems Analysis and Design (3) *Power system planning, studies, and design; time-domain modeling and analysis of power-system networks; power*

flow, stability, fault, and economic dispatch analysis; symmetrical components. Prerequisite: EE 443.

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 301L; recommended preparation: EE 483.*

EE 523 Advanced Biomedical Imaging (3) (Enroll in BME 525)

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 443.*

EE 525 Power System Protection (3) *Theory of system and equipment protection, characteristics of relays, relay coordination, and system considerations. Prerequisites: EE 443.*

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.

EE 527 Net-Centric Power-System Control (3, FaSpSm) *Control and stability of large-scale systems such as the electric power grid. Integration with information networks. Corequisite: EE 521; recommended preparation: EE 482.*

EE 528 Power Electronics (3) Fundamentals of switched-mode power converters operating under steady-state and transient conditions. Feedback control systems. Magnetic circuit design.

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 533 Network Processor Design and Programming (3, Sp) *Understanding of network processor architecture, applications, and other relevant issues. Program network processor and test under realistic network environment. Design and deploy custom network processor. Prerequisite: EE 457; recommended preparation: EE 450.*

EE 534 Materials Characterization (3) (Enroll in MASC 534)

EE 535 Mobile Communications (3, FaSpSm) *The mobile communication channel; techniques used to combat the channel; cellular communications; multiple-access techniques; example mobile communication systems. Prerequisite: EE 503.*

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. 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 539 Engineering Quantum Mechanics (3, Fa) Quantum mechanics for engineering majors who work with solid-state devices, quantum electronics, and photonics. Schroedinger equation, perturbation theory, electronic and optical processes.

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 Internet and Cloud Computing (3, Fa) *Principles and technologies of server clusters, virtualized datacenters, Grids/P2P, Internet clouds, social networks, Internet of Things (IoT), and their innovative applications. Recommended preparation: EE 450 or EE 457.*

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 301L, 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 or EE 503.*

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 464 or EE 465 or EE 503; recommended preparation: EE 549.*

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 364 and EE 470.*

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, FaSpSm) *Broadband network architectures and services, technologies for high-speed access and core networks, optical infrastructure for layered network architectures, high performance switch and router architectures. Prerequisite: EE 450 and EE 464 or EE 465 or EE 503.*

EE 556 Stochastic Systems (3, FaSpSm) *Stochastic system models, Dynamic programming, Linear quadratic control, Kalman filtering and estimation, System identification, approximate dynamic programming methods, adaptive control and online learning. Prerequisite: EE 464 or EE 465 or EE 503. Recommended preparation: EE 512 or EE 562a or ISE 538.*

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 nonparametric techniques; artificial neural networks. Corequisite: EE 441, EE 503.*

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 or EE 503. 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 503.*

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 or EE 465 or EE 503.*

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 or EE 503; 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 or EE 503.*

EE 569 Introduction to Digital Image Processing (3, FaSpSm) *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 or EE 503.*

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 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 Statistical Signal Processing (3) *Characterization of discrete-time random processes. Parametric and non-parametric spectral estimation, adaptive filtering, signal subspace methods, independent components analysis, non-Gaussian signal processing. Prerequisite: EE 503.*

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, Kanman-Bucy filters, separation principle, discrete linear optimal control systems. Prerequisite: EE 585; recommended preparation: EE 482, 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, FaSp) *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. Recommended preparation: EE 441; EE 464, or EE 503. Familiarity with MATLAB is required.*

EE 592 Computational Methods for Inverse Problems (3, FaSpSm) *Vector-space methods for solving inverse problems. Existence and uniqueness of solutions; conditioning and regularization; iterative algorithms; constrained optimization; applications in signal and image processing. Prerequisite: EE 483 and EE 441. Recommended preparation: EE 503.*

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, FaSpSm) *Finite field theory; Reed Solomon codes; algebraic codes; algebraic decoding methods; examples. Prerequisite: EE 441, EE 464 or EE 503.*

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 597 Wireless Networks (3, Fa) *Introduction to wireless networking technologies; fundamental architectural and design principles used at all protocol layers; optimization and performance evaluation using mathematical analysis and simulations. Prerequisite: EE 450, EE 464 or EE 465 or EE 503; recommended preparation: EE 467, familiarity with MATLAB and C programming.*

EE 598 Electrical Engineering Research Seminar (1, max 2) Introduction to research in electrical engineering. Topics vary by semester. May be repeated for up to one unit of credit for M.S. students, two units of credit for Ph.D. students. Open only to master's and doctoral students. Graded CR/NC.

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 Advanced Semiconductor Device Physics (3) *Fundamentals and limitations of nanoscale electronic and photonic semiconductor components. Engineering classical, mesoscale, and quantum electron*

and photon dynamics in advanced devices. *Recommended preparation: EE 471 or EE 539.*

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, FaSpSm) *Advanced topics in automatic speech recognition, speaker recognition, spoken dialogue, conversational multimedia interfaces. Recommended preparation: EE 519 and CSCI 544 and EE 464 or EE 503.*

EE 620 Advanced Topics in Applied Stochastic Models (3, FaSp) (Enroll in ISE 620)

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 635 Advanced Wireless Communications (3) *Fundamentals of advanced wireless systems, including multi-antenna, cognitive, and cooperative systems as well as exploration of current standards in wireless networks in use today. Prerequisite: EE 535; recommended preparation: basic programming course.*

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 648 Network Economics and Games (3) *Economics of networks; game theory, mechanism design and auctions in networks; spectrum sharing mechanisms in communications; pricing of differentiated services; network security. Prerequisite: EE 450 and EE 464 or EE 465 or EE 503.*

EE 649 Stochastic Network Optimization (3, FaSpSm) *Optimization of wireless and ad-hoc mobile networks; opportunistic scheduling, flow control; backpressure routing; queue stability; energy-delay and utility-delay tradeoffs. Prerequisite: EE 464 or EE 465 or EE 503.*

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 450 and EE 465 or EE 503; recommended preparation: EE 550 or CSCI 551.*

EE 652 Low-Power Wireless Networks (3, Fa) *Implementation of low-power wireless protocols for medium access, scheduling, multi-hop routing, congestion control, localization, synchronization. IP stack for the Internet of Things. Wireless sensor network applications. Prerequisite: EE 450; recommended preparation: CSCI 402, strong programming skills, and experience with Linux.*

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) *Scalable multiprocessor systems and clusters, virtual machine, service oriented architecture, network-based computing, peer-to-peer, grid and cloud based storage and computing, case studies. Prerequisite: EE 557; recommended preparation: EE 450.*

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 660 Machine Learning from Signals: Foundations and Methods (3, Fa) *Supervised, semi-supervised, and unsupervised machine learning; classification and regression. Model complexity, assessment, and selection; performance (error) on unseen data. Prerequisite: EE 441 and EE 503. Recommended preparation: EE 559 or CSCI 567.*

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, FaSpSm) *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 or EE 503.*

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

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 682 Law and Intellectual Property for Engineers (3, Sp) *Detailed introduction to the modern American legal system with a special focus on intellectual property doctrines. Recommended preparation: EE 464 or EE 503.*

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 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

Office of Graduate and Professional Programs Olin Hall of Engineering 106 (213) 740-4488 FAX: (213) 821-0851 *Email:* masters@gapp.usc.edu

Program Director: **Edward W. Maby, Ph.D.** **Email:** maby@usc.edu (213) 740-4706

Student Services Adviser: **Carolyn Suckow** *Email:* jecks@usc.edu (213) 821-0413

Stephen Schrank Early Career Chair in Civil and Environmental Engineering: **Burcin Becerik-Gerber, D.Des.**

Professors: Jiin-Jen Lee, Ph.D., P.E. (Civil and Environmental Engineering)*; John Silvester, Ph.D. (Electrical Engineering); James E. Moore, II, Ph.D. (Industrial and Systems Engineering, Civil and Environmental Engineering, Public Policy); Priya Vashishta (Chemical Engineering and Materials Science, Computer Science)

Associate Professors: Mansour Rahimi, Ph.D. (Industrial and Systems Engineering); Geoffrey R. Shiflett, Ph.D. (Aerospace and Mechanical Engineering)*

Assistant Professors: Burcin Becerik-Gerber, D.Des. (Civil and Environmental Engineering)

Professors of the Practice: Edward Maby, Ph.D. (Electrical Engineering); Azad Madni, Ph.D. (Astronautical Engineering, Systems Architecting and Engineering)

Research Associate: Julie Albright, Ph.D.

Recipient of university-wide or school teaching award.

Master of Science in Green Technologies

Green Technologies is a highly interdisciplinary degree program that emphasizes green systems and the environment, energy technology and efficiency, and sustainability and society. The discipline seeks opportunities for alternative sourcing, conservation, efficiency and repurposing through an understanding of product life cycles from origins to recycling or inevitable disposal. Green technologists will design products, processes and complex infrastructure systems to promote sustainable attributes of importance to the environment and the global community.

The Green Technologies program requires a minimum of 27 units (typically nine courses). At least 18 units must be at the 500-level or above, and at least 18 units must be completed in the Viterbi School of Engineering. These 18 units may reflect courses offered by other schools if cross-listed in a department in the Viterbi School. Students with B.S. degrees in engineering and science disciplines can be accepted into the program.

REQUIRED COURSES		units
Students are required to take two courses in each of three topical areas:		
Green Systems and the Environment (two courses)		
CE 515	Sustainable Infrastructure Systems	3
ISE 576	Industrial Ecology: Technology-Environment Interaction	3
Energy Technology and Efficiency (two courses)		
CHE 510	Energy and Process Efficiency, or	
AME 577	Survey of Energy and Power for a Sustainable Future	3
Also take only one of the following:		
EE 513	Solid State Energy Devices	3
EE 526	Renewable Energy in Power Systems	3
ENE 505	Energy and the Environment	3
Sustainability and Society (two courses)		
CE 469	Sustainable Design and Construction	3
Also take one of the following:*		
ARCH 519	Sustainability in the Environment: Infrastructures, Urban Landscapes, and Buildings	3
CE 567	Smart Infrastructures	3
ENE 502	Environmental and Regulatory Compliance	3
GEOG 581	Concepts for Spatial Thinking	4
MOR 566	Environmental Sustainability and Competitive Advantage	3
POSC 546	Seminar in Environmental Policy	4
PPD 692	Transportation and the Environment	4
PPDE 632	Sustainable Cities	4
Electives (three courses)		9

Electives shall be chosen in consultation with an adviser to develop technical specialization in an area of interest to the student. This may include up to 3 units of directed research.

* Additional courses from this list may be used to fulfill the elective requirement.

Daniel J. Epstein Department of Industrial and Systems Engineering

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Chair: Julia L. Higle, Ph.D.

Faculty

Daniel J. Epstein Chair in Industrial and Systems Engineering: Sheldon M. Ross, Ph.D.

Epstein Family Professor of Industrial and Systems Engineering: Jong-Shi Pang, Ph.D.

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

Gordon S. Marshall Early Career Chair in Engineering: Qiang Huang, Ph.D.

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

Helen N. & Emmett H. Jones Professorship in Engineering: Milind Tambe, Ph.D. (Computer Science)

TRW Professor of Software Engineering: Barry Boehm, Ph.D. (Computer Science)

Professors: Barry Boehm, Ph.D. (Computer Science); Maged Dessouky, Ph.D.*; Randolph Hall, Ph.D.; Julia Higle, Ph.D.; Carl F. Kesselman, Ph.D. (Computer Science); Behrokh Khoshnevis, Ph.D. (Civil and Environmental Engineering; Aerospace and Mechanical Engineering); Stephen C-Y Lu, Ph.D. (Aerospace and Mechanical Engineering, Computer Science); Najmedin Meshkati, Ph.D. (Civil and Environmental Engineering)*; James E. Moore II, Ph.D. (Civil and Environmental Engineering; Public Policy); Jong-Shi Pang, Ph.D.; Sheldon M. Ross, Ph.D.; Suvrajeet Sen (Electrical Engineering; Computer Science); F. Stan Settles, Ph.D. (Astronautical Engineering); Milind Tambe, Ph.D. (Computer Science); Detlof von Winterfeldt (Public Policy)

Associate Professors: Yong Chen, Ph.D.; Qiang Huang, Ph.D.; Mansour Rahimi, Ph.D.

Adjunct Professors: Paul J. Kern; Michael Mann, Ph.D.; Neil Siegel, Ph.D.

Adjunct Associate Professors: Tasos Sioukas, Ph.D.; Marilee Wheaton, M.S.

Research Professor: Yigal Arens, Ph.D.

Research Associate Professor: Fernando Ordoñez, Ph.D. (Computer Science)

Research Assistant Professor: Greg Placencia, Ph.D.

Adjunct Research Professors: Wanda M. Austin, Ph.D.; Mohamed I. Dessouky, Ph.D.

Associate Professors of the Practice of Industrial and Systems Engineering: Geza Bottlik, Engineer, P.E.; Nitin Kale, M.S. (Information Technology Program); Kurt Palmer, Ph.D.*

Senior Lecturers: Dana Sherman, Esq. (Civil and Environmental Engineering); Richard Vawter, M.S. (Information Technology Program)

Emeritus Professors: Gerald A. Fleischer, Ph.D., P.E.; Homer H. Grant, M.S.; Ralph Keeney, Ph.D. (Data Sciences and Operations); Peter Will, Ph.D. (Astronautical Engineering, Chemical Engineering)

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 recommended by the department chair. The adviser 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.

Undergraduate Degree Requirements

Undergraduate Education Program Mission

The mission of the Daniel J. Epstein Department of Industrial and Systems Engineering undergraduate program is to:

- Provide students: the skills and knowledge to obtain employment and achieve leadership with the industrial and systems engineering profession or to proceed with graduate education; the intellectual resources to continue life-long learning; and the knowledge of professional ethics and critical reasoning skills necessary for contributing to society.

- Provide employers of industrial and systems engineering professionals with candidates who are technically competent, business aware, collaborative, able to communicate effectively, and ethically grounded.

- Maintain and enhance the reputation of the Epstein department within the engineering, business and academic communities.

Undergraduate Program Educational Objectives

Graduates of the Bachelor of Science in Industrial and Systems Engineering program are prepared to achieve any of the following accomplishments:

- Obtain employment in an organization that values people who demonstrate both technical competence and business awareness.

- Pursue graduate or professional education.

- Assume a leadership role in their employment organization or community.

- Utilize critical reasoning, collaboration and creativity to contribute to society.

Undergraduate Program Criteria

The program leading to a Bachelor of Science in Industrial and Systems Engineering prepares graduates to design, develop, implement, and improve integrated systems that include people, materials, information, equipment and energy. The curriculum includes in-depth instruction to accomplish the integration of systems using appropriate analytical, computational, and experimental practices.

For additional information, visit usc.edu/dept/ise.

Bachelor of Science in Industrial and Systems Engineering

The Epstein Department of Industrial and Systems Engineering offers a Bachelor of Science degree in Industrial and Systems Engineering. Additionally, information systems engineering exists as an emphasis within this industrial and systems engineering program major. An area of emphasis appears in parentheses after the primary major name on the transcript.

The requirement for the degree is 128 units. A cumulative grade point average of C (2.0) is required for all upper division courses applied towards the major, regardless of the department in which the courses are taken. See the common requirements for undergraduate degrees.

Composition/Writing Requirement		UNITS
WRIT 150*	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		units
General education* +		20
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
major requirements		UNITS
Business		
ACCT 410x	Foundations of Accounting	4
Engineering		
ENGR 102	Engineering Freshman Academy	2
Electrical Engineering		
AME 341a	Mechnoptonics 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 and Scheduling	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 150.

** 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
Emphasis in Information Systems Engineering

The requirement for the degree with an emphasis in information systems engineering is 128 units. A cumulative grade point average of C (2.0) is required for all upper division courses applied towards the major, regardless of the department in which the courses are taken. Students must choose either the computer science track or the information and operations management track. See the common requirements for undergraduate degrees.

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 150	Writing and Critical Reasoning — Thematic Approaches	4
WRIT 340	Advanced Writing	3
General Education		**units**
General education* +		20
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
Engineering		
ENGR 102	Engineering Freshman Academy	2
Computer Science Track		**UNITS**
Computer Science		
CSCI 103L	Introduction to Programming	3
CSCI 104L	Data Structures and Object Oriented Design	4
CSCI 201L	Principles of Software Development	4
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/data sciences and operations electives		6
Approved engineering elective		3
Free electives		11
Information and Operations Management Track		**UNITS**
Business		
DSO 431	Foundations of Digital Business Innovation	4
DSO 433	Business Process Design	4
DSO 435	Enterprise Data Architecture	4
Computer Science		
CSCI 101	Fundamentals of Computer Programming	3
ITP 482	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/data sciences and operations 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/DSO 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/DSO Electives: ITP 215Lx, ITP 320Lx, ITP 325x, ITP 454x, ITP 457x, ITP 486, ITP 487, DSO 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

Graduate Degree Requirements

Analytics Program
Ethel Percy Andrus
Gerontology Center 240
(213) 740-4893

The Master of Science in Analytics is designed to satisfy the growing demand for professionals equipped with significant technical and quantitative training in the fundamentals of analytics for solving engineering and management problems in today's data-extensive digital world.

Analytics is a multidisciplinary field that relates the application of engineering approaches and methods to the analysis and management of engineering and enterprise processes based on data. Learning objectives of this program involve data collection, cleansing, fusing and curating, for the purpose of analyzing trends, discovering patterns and building decision models for well-reasoned decision support. Rigorous mathematical modeling and computational methods tools are at the heart of the program.

Graduates of this program will be prepared to convert data into meaningful information, embedded in decision support systems that can help organizations make important operational decisions and help set strategic direction and policy.

Master of Science in Analytics

The core of the M.S. in Analytics program consists of six foundational courses, and four elective courses, totaling 30 units. The foundational courses cover the basic topics of data science and management, statistical methods, optimization, simulation and other operations research tools. The elective courses allow students to deepen their technical skills and expose them to the applied domains where analytics is much needed; some of these domains include electricity markets, supply chains and logistics, health care systems, and transportation.

Required courses		Units
DSO 529	Advanced Regression Analysis	3
INF 551	Foundations of Data Management	3
ISE 515	Engineering Project Management	3
ISE 529	Engineering Data Analytics	3
ISE 530	Optimization Methods for Analytics	3
ISE 580	Performance Modeling and Simulation	3

Electives		Units
ISE Elective		3
INF or CSCI Elective		3
Electives subject to adviser approval		6
Total units for the degree:		30

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/MBA 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 21 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.

Required courses (6 units)		Units
ISE 500	Engineering Management Decisions and Statistics	3
ISE 561	Economic Analysis of Engineering Projects	3
At least one course from the accounting area is required (3 units)		**Units**
CE 502	Construction Accounting and Finance	3
ISE 566	Financial Accounting Analysis for Engineering	3
At least two courses from the engineering management area are required (6 units)		**Units**
ISE 515	Engineering Project Management	3
ISE 544	Management of Engineering Teams	3
ISE 564	Performance Analysis	3
ISE 565	Law and Finance for Engineering Innovation	3
At least one course from the quantitative methods area is required (3 units)		**Units**
ISE 513	Inventory Systems	3
ISE 514	Advanced Production Planning and Scheduling	3
ISE 525	Design of Experiments	3
ISE 527	Quality Management for Engineers	3
ISE 530	Optimization Methods for Analytics	3

Electives (12 units):
Four courses for at least 12 units chosen to form a coherent program with the consent of the adviser.

Health Systems Management Engineering Program

This program is jointly sponsored by the Epstein Industrial and Systems Engineering Department and the USC This degree is in revision, and applications are not currently being accepted. Interested students should consider the Master of Health Administration program in the USC Price School of Public Policy.

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**
Systems Design		
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
Production		
ISE 511L	Mechatronic Systems Engineering	3
ISE 513	Inventory Systems	3
ISE 517	Modern Enterprise Systems	3
SAE 551	Lean Operations	3
Systems Performance		
ISE 544	Management of Engineering Teams	3
ISE 564	Performance Analysis	3
ISE 570	Human Factors in Engineering	3
Information Systems		
ISE 580	Performance Modeling and 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
Adviser 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	Performance Modeling and Simulation	3

ISE 580			
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 adviser		3	
Two electives, approved by faculty adviser		**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.

Master of Science in Systems Architecting and Engineering

See the listing under Systems Architecting and Engineering. The program is available via distance education.

Dual Degree Program (M.S., Electrical Engineering / M.S., Engineering Management)

See listing in the Electrical Engineering section.

Dual Degree Program (M.S., Industrial and Systems Engineering / MBA)

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 MBA program is 48 including all required courses in an MBA 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.

Required courses (minimum 18 units)		units
ISE 514	Advanced Production Planning and Scheduling	3
ISE 515	Engineering Project Management	3
ISE electives (choose one from each group)		9 units
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	Performance Modeling and 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 adviser 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 Health Systems Operations

This 17-unit graduate certificate is jointly sponsored by the Epstein Industrial and Systems Engineering Department and the USC Price School of Public Policy (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 USC Price School of Public Policy'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 Methods and Applications	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, and	2
PPD 517	Concepts and Practices in Managing Health Care Organizations, or	2
PPD 514	Economic Concepts Applied to Health	4
PPD 557	Modeling and Operations Research (4), or	
ISE 530	Optimization Methods for Analytics (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. 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 Data Sciences and Operations in the USC Marshall School of Business. See here for program requirements.

Graduate Certificate in Systems Architecting and Engineering

See listing under Systems Architecting and Engineering. The program is available via distance education.

Graduate Certificate in Transportation Systems

This abbreviated interdisciplinary program is offered jointly with the Astani Department of Civil and Environmental Engineering and the USC Price School of Public Policy. See listing under Civil Engineering.

Graduate Certificate in System Safety and Security

Applications for this program are not currently being accepted.

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, FaSp) *Techniques for handling uncertainties in engineering design: discrete and continuous random variables; expectations, probability distributions and transformations of random variables; limit theorems; approximations and applications. Prerequisite:* MATH 126.

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, FaSp) *Facilities layout and design: material handling and transportation; site selection and sourcing; supply chain management. Prerequisite:* ISE 330 and 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.

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.

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

ISE 404 Business and Intellectual Property Law for Engineers (3) (Enroll in CE 404)

ISE 410 Production II: Planning and Scheduling (3, FaSp) *Production planning, forecasting, scheduling, and inventory; computer integrated decision systems in analysis and control of production systems. Prerequisite:* ISE 330.

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, FaSp) *Model design to simulate discrete event systems with basic input and output analysis using high order languages, applied to industrial systems analysis and design problems. Prerequisite:* CSCI 101L and 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 482 Engineering Database Applications (3) (Enroll in ITP 482)

ISE 487Lx Data Warehouses and Business Intelligence (3) (Enroll in ITP 487)

ISE 488x Managing Supply Chains with Advanced Planning and Optimization (3) *(Enroll in ITP 488x)*

ISE 490x Directed Research (1-8, max 12, 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. Prerequisite: ISE 225 and ISE 310 and IOM 435 or ISE 382. b: Group work on an industrial engineering design problem in an organization. Not available for graduate credit. Senior standing in industrial and systems engineering. Open only to industrial and systems engineering majors. Prerequisite: ISE 435 and ISE 370 or ISE 470.*

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 500 Engineering Management Decisions and Statistics (3, FaSpSm) Case-based decision and statistical analysis. Framing engineering management situations with statistical methods. Experiments, regression, ANOVA, hypothesis, factor analysis. Open only to fifth-year seniors and master's students.

ISE 502 Construction Accounting and Finance (3) (Enroll in CE 502)

ISE 507 Six-Sigma Methods and Applications (3, FaSpSm) Comprehensive study of Six Sigma and Lean metrics, methods, and systems with their applications to manufacturing, services, quality improvement and management.

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 Mechatronic Systems Engineering (3, Sp) *Use of mechanical, electrical, and computer engineering, math, and computer science to design of high performance and sophisticated products and processes and systems involving mechatronic. Recommended preparation:* bachelor's degree in engineering or physical sciences, and preliminary knowledge of programming in C.

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 517 Modern Enterprise Systems (3, FaSp) Managing the process design, interfaces and resources of service and manufacturing systems, based on the state of their processes.

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 529 Engineering Data Analytics (3, FaSp) *Theory and methods of data analytics emphasizing engineering applications: multivariate statistics, supervised learning, classification, smoothing and kernel methods, support vector machines, discrimination analysis, unsupervised learning. Prerequisite:* DSO 529.

ISE 530 Optimization Methods for Analytics (3, FaSp) *Linear Programming, Integer Programming, Meta-heuristics and Multi-objective optimization. Recommended preparation:* Calculus III, Linear Algebra and Computer Programming.

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 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 554 Innovation and the Engineering Enterprise (3) Examination of innovation in engineering enterprises including human behavior and human resources, organizational development, engineering management, business structures, financing the enterprise and intellectual property.

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 (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 568 Machine Learning (3, Fa) (Enroll in CSCI 567)

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 573 Work Physiology (3) Survey of metabolic processes in the performance of physical work, study of individual and environmental factors affecting these processes.

ISE 574 Probabilistic Reasoning (3, Fa) (Enroll in CSCI 573)

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 Performance Modeling and Simulation (3, FaSp) *Introduction to modeling and analysis of stochastic systems, with an emphasis on analytic methods for Markovian systems and discrete-event simulation of non-Markovian systems. Recommended preparation:* probability and statistics, including hypothesis testing and introductory computer programming.

ISE 581 Negotiation For Engineering Management (3, Sp) Decision making techniques for the engineering manager including negotiation principles, contract negotiation, dispute resolution, auctions, bidding, voting and coalition formation.

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 620 Advanced Topics in Applied Stochastic Models (3, FaSp) *Applications of continuous time Markov chains, semi-Markov processes, martingales, random walks, and coupling techniques to models of industrial systems. Queueing, reliability, and optimization models. Prerequisite:* ISE 538.

ISE 630 Foundations of Optimization (3, Sp) *Convex sets, convex functions, structures of optimization problems, Lagrangian and conjugate duality. First and second order optimality conditions; applications in engineering and management. Recommended preparation:* Calculus III and Linear Algebra.

ISE 632 Network Flows and Combinatorial Optimization (3, Sp) *Combinatorial optimization, particularly graph problems. Shortest paths, max flow, minimum cost flows, spanning trees, matroids, submodular functions. Bipartite and general matchings, polyhedral combinatorics, total unimodularity. (Duplicates credit in ISE 532.) Prerequisite: ISE 536; recommended preparation:* familiarity with the theory of linear programming and with mathematical proofs; knowledge of linear algebra.

ISE 638 Stochastic Optimization (3, FaSp) *Stochastic linear and integer programming, multi-stage stochastic programming, application, models and algorithms. Recommended preparation:* A first graduate course in optimization and the ability to program in a high level language are essential.

ISE 645 Uncertainty Modeling and Stochastic Optimization (3, Sp) (Enroll in CE 645)

ISE 651 Seminar in Industrial and Systems Engineering (1, max 4, FaSp) *Current research, guest speakers in the field; review papers; guidance in preparing research proposals and special projects. (Duplicates credit in the former ISE 650abc.)* Open only to fifth-year seniors and master's students. Graded CR/NC.

ISE 670 Advanced Analysis of Algorithms (3, Fa) (Enroll in CSCI 670)

ISE 671 Randomized Algorithms (3, Sp) (Enroll in CSCI 671)

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.

Informatics Program

Ethel Percy Andrus
Gerontology Center 240
(213) 740-4739
Email: informat@usc.edu

Director: Herbert Schorr, Ph.D.

Assistant Director: Winnie Callahan, Ed.D.

Faculty

Professors: Barry Boehm, Ph.D. (Computer Science, Industrial and Systems Engineering); Ramesh Govindan, Ph.D. (Computer Science, Electrical Engineering); Julia Higle, Ph.D. (Industrial and Systems Engineering); Carl Kesselman, Ph.D. (Industrial and Systems Engineering, Computer Science); Neno Medvidovic, Ph.D. (Computer Science); Shri Narayanan, Ph.D. (Electrical Engineering, Computer Science, Linguistics, Psychology); Viktor Prasanna, Ph.D. (Electrical Engineering); Suvrajeet Sen, Ph.D. (Industrial and Systems Engineering, Electrical Engineering, Computer Science); Cyrus Shahabi, Ph.D. (Computer Science); Gaurav Sukhatme, Ph.D. (Computer Science, Electrical Engineering); Milind Tambe, Ph.D. (Computer Science, Industrial and Systems Engineering); Priya Vashishta, Ph.D. (Physics, Computer Science, Biomedical Engineering)

Assistant Professor: Yan Liu, Ph.D. (Computer Science)

Research Professors: Herbert Schorr, Ph.D. (Computer Science); William Swartout, Ph.D. (Computer Science)

Research Associate Professor: Clifford Neuman, Ph.D. (Computer Science)

Professor of the Practice: Roger Schell, Ph.D.

Senior Lecturer: Blaine Burnham, Ph.D.

Lecturer: Lyndon Pierson

Master of Cyber Security

Program Director: Blaine Burnham, Ph.D.

The Master of Cyber Security (MCBS) is intended for graduate students who desire to: obtain jobs in which knowledge and skills for the creation and analysis of trustworthy systems and networks are required and continue an education path toward a doctorate degree with focus on information security. It is also for individuals who are in degree programs or job fields that have some responsibility with information security and who desire enhanced knowledge and skills.

Upon completion of this program, students will have learned the fundamental theory and practices for designing, engineering and operating high assurance secure information systems. They will be well versed in the challenges and problems of secure operating systems, secure aware applications, secure networking, use of cryptography and key management. They will understand how to develop and formally model a security policy, and how sound policy taxonomy drives technology decisions. Students will gain the knowledge and concepts necessary to administer environments that require high levels of information security. Students will understand the value of assets, the business model of threat, the distinct threat categories from user abuse to malicious subversion and mitigation strategy. They will understand that a foundation of sound principles critically influences why some information security plans succeed and why others fail. Students will have hands-on experience in situations that simulate real-world scenarios with all technical and theoretical situations through extensive laboratory work, which will be designed by current and former information security practitioners.

Requirements for completion (27 units minimum)

Required courses (18 units)		Units
INF 520	Foundations of Information Security	3
INF 521	Applications of Cryptography to Information Security Problems	3
INF 522	Policy: The Foundation for Successful Information Assurance	3
INF	Assurance in Cyberspace Applied to	3
523	Information Security	
INF 524	Distributed Systems and Network Security	3
INF 527	Secure Systems Engineering	3
Elective courses (choose three, 9-10 units)		units
CSCI 530	Security Systems	4
CSCI 531	Applied Cryptography	3
INF 525	Trusted System Design, Analysis and Development	3
INF 526	Secure Systems Administration	3
INF 528	Computer and Network Forensics	3

Master of Science in Data Informatics

Program Director: Herb Schorr, Ph.D.

The social emergence of large data environments and infrastructures (Big Data) in diverse domains and uses has spawned a requirement for analysis of the information contained. Past experience has shown that extracting value from large information stores can often be difficult due to the intrinsic nature of data, and the limits on ability to intelligently mine the information to add value to the organization.

The USC Viterbi Master of Science in Data Informatics provides students with the knowledge and skill to: a) understand and contribute toward the significant technical challenges created by large data environments, including architecture, security, integrity, management, scalability, artificial intelligence topics, and distribution; b) understand the principles and application of informatics, and the goals of enterprise intelligence; and c) utilize technical/engineering skills coupled with informatics capabilities to provide enterprise-centric solutions to stakeholders. The degree features application of knowledge and skill in hands-on type experiences, with the goal of having students leave the program having "lived in the data.";

Students will understand the overall field of data analytics, the role of the analyst and/or data scientist, and the domains where informatics skills can be applied to critical organization missions. They will understand how data management, data visualization, data mining, and artificial intelligence techniques (specifically machine learning) are critical to the analysis process, and how these can be applied to real world challenges. Through an extensive elective track, they can find the specializations that will help them better prepare themselves for the area(s) of analytics in which they hope to contribute. Finally, students will participate in a unique professional practicum that will focus on real world challenges, brought in by external customers.

Requirements for completion (27 units minimum)

Required courses (18 units)		Units
INF 550	Overview of Data Informatics in Large Data Environments	3
INF 551	Foundations of Data Management	3
INF 552	Machine Learning for Data Informatics	3
INF 553	Foundations and Applications of Data Mining	3
INF 555	User Interface Design, Implementation, and Testing	3
INF 560	Data Informatics Professional Practicum	3
Elective courses (choose three, 9-10 units)		units
CSCI 686	Advanced Big Data Analytics	3
CSCI	Machine Learning	3

CSCI 567		
CSCI 548	Information Integration on the Web	3
CSCI 561	Foundations of Artificial Intelligence	3
CSCI 585	Database Systems	3
CSCI 530	Security Systems	4
CSCI 485	File and Database Management	3
CSCI 572	Information Retrieval and Web Search Engines	3
INF 520	Foundations of Information Security	3
INF 522	Policy: The Foundation of a Successful Information Assurance Program	3

Courses of Instruction

INFORMATICS PROGRAM (INF)

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

INF 520 Foundations of Information Security (3) *Threats to information systems; technical and procedural approaches to threat mitigation; secure system design and development; mechanisms for building secure security services; risk management. Recommended preparation:* Background in computer security preferred. Recommended previous courses of study include computer science, electrical engineering, computer engineering, management information systems, and/or mathematics.

INF 521 Application of Cryptography to Information Security Problems (3) *Application of cryptography and cryptanalysis for information assurance in secure information systems. Classical and modern cryptography. Developing management solutions. Recommended preparation:* Previous degree in computer science, mathematics, computer engineering, or informatics; understanding of number theory and programming background are helpful.

INF 522 Policy: The Foundation for Successful Information Assurance (3) *Policy as the basis for all successful information system protection measures. Historical foundations of policy and transition to the digital age. Detecting policy errors, omissions and flaws. Recommended preparation:* Background in computer security, or a strong willingness to learn. Recommended previous courses of study include degrees in computer science, electrical engineering, computer engineering, management information systems, and/or mathematics.

INF 523 Assurance in Cyberspace Applied to Information Security (3) *Assurance as the basis for believing an information system will behave as expected. Approaches to assurance for fielding secure information systems that are fit for purpose. Recommended preparation:* Prior degree in computer science, electrical engineering, computer engineering, management information systems, and/or mathematics. Some background in computer security preferred.

INF 524 Distributed Systems and Network Security (3) *Fundamentals of information security in the context of distributed systems and networks. Threat examination and application of security measures, including firewalls and intrusion detection systems. Recommended preparation:* Prior degree in computer science, mathematics, computer engineering, or informatics. It is recommended that students have a working understanding of communication networks and computer architecture, and some programming facility.

INF 525 Trusted System Design, Analysis and Development (3) *Analysis of computer security and why systems are not secure. Concepts and techniques applicable to the design of hardware and software for Trusted Systems. Recommended preparation:* Prior degree in computer science, mathematics, computer engineering, or informatics; advanced knowledge of computer architecture, operating systems, and communications networks will be valuable.

INF 526 Secure Systems Administration (3) *The administrator's role in information system testing, certification, accreditation, operation and defense from cyber attacks. Security assessment. Examination of system vulnerabilities. Policy development. Recommended preparation:* Previous degree in computer science, mathematics, computer engineering, informatics, and/or information security undergraduate program. Also, it is highly recommended that students have successfully completed course work involving policy and network security.

INF 527 Secure Systems Engineering (3) *The process of designing, developing and fielding secure information systems. Developing assurance evidence. Completion of a penetration analysis. Detecting architectural weaknesses. Case studies. Recommended preparation:* Previous degree in computer science, mathematics, computer engineering, or informatics; moderate to intermediate understanding of the fundamentals of information assurance, and distributed systems and network security. Knowledge and skill in programming.

INF 528 Computer and Network Forensics (3) *Preservation, identification, extraction and documentation of computer evidence stored on a computer. Data recovery; cryptography; types of attacks; steganography; network forensics and surveillance. Recommended preparation:* Previous degree in computer science, mathematics, computer engineering, or informatics; a working understanding of number theory and some programming knowledge will be helpful.

INF 550 Overview of Data Informatics in Large Data Environments (3, FaSp) *Fundamentals of big data informatics techniques. Data lifecycle; the data scientist; machine learning; data mining; NoSQL databases; tools for storage/processing/analytics of large data set on clusters; in-data techniques. Recommended preparation:* Basic understanding of engineering and/or technology principles; basic programming skills; background in probability, statistics, linear algebra and machine learning.

INF 551 Foundations of Data Management (3, FaSp) *Function and design of modern storage systems, including cloud; data management techniques; data modeling; network attached storage, clusters and data centers; relational databases; the map-reduce paradigm. Recommended preparation:* INF 550 taken previously or concurrently; understanding of operating systems, networks, and databases; experience with probability, statistics, and programming.

INF 552 Machine Learning for Data Informatics (3, FaSp) *Practical applications of machine learning techniques to real-world problems. Uses in data mining and recommendation systems and for building adaptive user interfaces. Recommended preparation:* INF 550 and INF 551 taken previously or concurrently; knowledge of statistics and linear algebra; programming experience.

INF 553 Foundations and Applications of Data Mining (3, FaSp) *Data mining and machine learning algorithms for analyzing very large data sets. Emphasis on Map Reduce. Case studies. Recommended preparation:* INF 550, INF 551 and INF 552. Knowledge of probability, linear algebra, basic programming, and machine learning.

INF 554 Information Visualization (3, FaSp) Graphical depictions of data for communication, analysis, and decision support. Cognitive processing and perception of visual data and visualizations. Designing effective visualizations. Implementing interactive visualizations.

INF 555 User Interface Design, Implementation, and Testing (3, FaSp) *Understand and apply user interface theory and techniques to design, build and test responsive applications that run on mobile devices and/or desktops. Recommended preparation:* Knowledge of data management, machine learning, data mining, and data visualization.

INF 556 User Experience Design and Strategy (3, FaSp) *The practice of User Experience Design and Strategy principles for the creation of unique and compelling digital products and services. Open only to Data Informatics majors. Recommended preparation:* Basic familiarity with web development and/or graphic design using a digital layout tool.

INF 560 Data Informatics Professional Practicum (3, FaSp) *Student teams working on external customer data analytic challenges; project/presentation based; real client data, and implementable solutions for delivery to actual stakeholders; capstone to degree. Recommended preparation:* Knowledge of data management, machine learning, data mining, and data visualization.

INF 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.

Information Technology Program

Olin Hall 412
(213) 740-4542
Email: itp@usc.edu
itp.usc.edu

Director: Michael Crowley, Ph.D.

Associate Professor of Engineering Practice: Nitin Kale, M.S.

Senior Lecturers: Joseph Greenfield, M.S.; Tom Sloper, B.A.

Instructors: Patrick Dent, M.S.; Jennifer Kassar, B.A.; Nathan Greenfield, M.S.; Trina Gregory, B.A.; Sanjay Madhav, B.S.; Rob Parke, M.S.; Chi So, M.S.; Ashish Soni, M.S.; David Tang, M.S.; Richard Vawter, M.S.; Lance Winkel, MFA

Adviser: Lisa Mataczynski, Ed.D.

ITP courses are open to all USC students.

Minors

ITP minors are open to undergraduate students in all majors.

To apply for a 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.

ITP Minors:

3-D Animation

Applied Computer Security

Computer and Digital Forensics

Computer Programming

Enterprise Information Systems

Innovation: The Digital Entrepreneur

Mobile App Development

Video Game Design and Management

Video Game Programming

Web Technologies and Applications

Viterbi School of Engineering Students

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 – cinematic arts, fine arts and information technology.

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
FADW 101	Introduction to 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.

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
ELECTIVE (4 units)		**Units**
ITP 425x	Web Application Security	4
ITP 457	Network Security	4
ITP 475x	Advanced Digital Forensics	4

Minor in Computer and Digital Forensics

The computer and digital forensics minor combines both theoretical concepts and practical skills to prepare students for a career as a digital forensics investigator. Students will study various areas of cyber-forensics, including forensic methodologies and processes, digital evidence-gathering and preservation, investigations and examinations, and court presentation. Electives are available depending on the students' academic and professional goals.

Requirements for completion (core courses plus electives)

Minimum units: 18

REQUIRED COURSES (4 COURSES, 12 UNITS)		Units
ITP 125Lx	From Hackers to CEOs: Introduction to Information Security	2
ITP 375x*	Digital Forensics	3
ITP 475x*	Advanced Digital Forensics	4
ITP 479	Cyber Law and Privacy	3
FORENSIC ELECTIVEs (CHOOSE two, 6 UNITS)		**Units**
ITP 325x*	Ethical Hacking and Systems Defense	3
ITP 445*	Macintosh, OSX and iOS Forensics	3
ITP 446*	Cyber Breach Investigations	3
ITP 447*	Mobile Device Security and Forensics	3
ITP 448*	Cyber Litigation Support	3

*Prerequisite required

Minor in Computer Programming

The minor in computer programming focuses on the practical programming skills necessary to solve problems in a variety of domains including on desktops, laptops, mobile devices, the Web, the cloud and for video games. Upon completion of the minor, students will have strong experience with the application of programming languages in several different contexts.

Students with a declared major in computer science, computer science and computer engineering, computer science (games), or computer science and business administration are not eligible for this minor. Students with a declared minor in computer science are likewise not eligible.

Requirements for completion (two core courses plus 12 units of electives)

Minimum units: 17

CORE COURSES (5 UNITS)		Units
ITP 165x*	Introduction to C++ Programming	2
ITP 365x	Managing Data in C++	3
ELECTIVE COURSES (12 UNITS)		**Units**
ITP 341x	App Development for Phones and Tablets	3
ITP 342L	Mobile Application Development	3
ITP 368x	Programming Graphical User Interfaces	3
ITP 380	Video Game Programming	4
ITP 404x**	Modern Technologies of Web Development	3
ITP 435x	Professional C++	3
ITP 437x	Secure Programming	3
ITP 439x	Compiler Development	3

*ITP 109x or ITP 115 can be substituted for ITP 165x, though ITP 165x is recommended.

**ITP 404x has additional prerequisites outside the minor, though these prerequisites can be waived for students in the minor (subject to faculty approval).

Minor in Enterprise Information Systems

The 21st century has seen tremendous growth in global enterprises, which has required robust and integrated information systems to support streamlined business processes. These Enterprise Information Systems, also known as Enterprise Resource Planning (ERP) systems, have continued to mature and dominate the information systems of corporations. Most Fortune 500 companies have adopted ERP systems. This minor combines business process management and information technology to prepare students for technical careers as well as business consulting in the ERP domain. Students will study various areas of ERP implementation, configuration, business intelligence, security and supply chain management. Electives are available depending on the students' academic and professional goals.

Requirements for completion (three core courses plus minimum 7 units of electives)

Minimum units: 16

REQUIRED COURSES (10 units)		Units
ITP 320x	Enterprise Wide Information Systems	4
ITP 422	Configuring Enterprise Resource Planning Systems	3
ITP 454x	Enterprise Resource Planning, Design, and Implementation	3
ELECTIVES (choose minimum 6 units of which minimum 3 units should have ITP prefix)		**units**
ACCT 371a	Introduction to Accounting Systems	2
ACCT 371b	Introduction to Accounting Systems	2
ACCT 410x	Foundations of Accounting	4
ACCT 478	Accounting Systems Design	4
ACCT 479	Accounting Systems Development	4
BUAD 311	Operations Management	4
DSO 431	Foundations of Digital Business Innovation	4
DSO 433	Business Process Design	4
DSO 435	Enterprise Data Architecture	4
ISE 382	Database Systems: Concepts, Design and Implementation	3

ITP 421x	Advanced Programming for Enterprise Information Systems	3
ITP 455Lx	Enterprise Information Portals	3
ITP 470x	Information Technology Practicum	1-4, max 8
ITP 486	Securing and Auditing Enterprise Resource Planning Systems	3
ITP 487	Data Warehouses and Business Intelligence	3
ITP 488x	Managing Supply Chains with Advanced Planning and Optimization	3
PPD 318	Financial Accounting in Public and Nonprofit Organizations	4

Minor in Innovation: The Digital Entrepreneur

The Minor in Innovation: The Digital Entrepreneur is jointly sponsored by the Information Technology Program in the Viterbi School of Engineering and the Lloyd Greif Center for Entrepreneurial Studies in the USC Marshall School of Business. The minor is designed for students from a range of backgrounds who are interested in starting their own digital ventures, working for start-up companies, or pursuing traditional jobs with large corporations and consulting firms that may involve launching new digital business units. Students will learn all major elements of launching a digital venture including ideation, feasibility analysis, high-tech product management, online customer acquisition, technology implementation, online business models and monetization. Students will work on launching a digital venture in a team-based environment in the capstone class.

The Information Technology Program in the Viterbi School of Engineering handles advising and admissions relating to the minor, consulting as needed with the Grief Center for Entrepreneurial Studies in the Marshall School of Business.

Requirements for completion (six core courses plus minimum 6 units of electives)

Minimum units: 26

Required courses (20 units)		units
BAEP 451	The Management of New Enterprises	4
BAEP 452*	Feasibility Analysis	4
ITP 466x	Building the High-Tech Startup	4
ITP 476x	Technologies for Interactive Marketing	4
ITP 496x*+	The Digital Startup Launchpad Lab	2
(capstone course; Corequisite: BAEP 496)		
BAEP 496*+	The Digital Startup Launchpad	2
Elective courses (6 units)		units
BAEP 423	Management of Small Businesses	4
BAEP 460	Seminar in Entrepreneurship	2
BUAD 304	Organizational Behavior and Leadership	4
BUAD 307	Marketing Fundamentals	4
IOM 462	Managing a Small Business on the Internet	2
ITP 310Lx	Design for User Experience	3
MKT 425*	Marketing on the Internet	4

* Prerequisite required

+ITP 496 and BAEP 496 must be taken in the same semester.

Minor in Mobile App Development

Students will study and gain experience with the technologies, tools, frameworks and languages that are most commonly used in developing apps for mobile devices such as smartphones and tablets. They will learn the basics of the programming languages, how to design mobile interfaces, how to use the libraries to build apps that have the proper look and feel, how to design and handle user input, and other aspects. Students will go through the process of building a mobile app from idea to product. Students will learn the fundamental principles of mobile apps, so that they will be prepared for the new technologies and frameworks that are constantly being developed.

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 (five core courses plus two electives)

Minimum units: 20

Required courses (14 units)		UNITS
Choose one from the following (2 units):		
ITP 109x	Introduction to Java Programming	2
ITP 115	Programming in Python	2
ITP 165x*	Introduction to C++ Programming	2
Choose one from the following (3 units):		
ITP 341x	App Development for Phones and Tablets	3
ITP 342L	Mobile Application Development	3
All of the following courses (9 units):		
ITP 140	Mobile Application Technologies	2
ITP 365x*	Managing Game Data	3
ITP 442	Mobile App Project	4
Electives (choose two courses for a minimum of 6 units)		UNITS
ITP 310Lx	Design for User Experience	3
ITP 341x	App Development for Phones and Tablets	3
ITP 342L	Mobile App Development	3
ITP 344x	Advanced Topics in Mobile App Development	3
ITP 382x	Mobile Game Programming	3
ITP 435x	Professional C++	3

* ITP 165x and ITP 365x can be waived for students who have taken CSCI 103 and CSCI 104. However, these students must take an additional elective course in order to have the appropriate number of upper-division units.

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. 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.

Requirements for completion

Minimum units: 22

Required courses (22 units minimum)		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
And at least 6 elective units from the following:		
ITP 391abx	Video Game Project Management	4, 2
ITP 393x	Video Game Design Documents	2
ITP 491x	Level Design and Development for Video Games	4

* It is recommended to take an introductory programming course before taking CTIN 483. Suggested courses: ITP 109, ITP 115, ITP 165.

** 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.

This minor features an optional capstone that is a team-based, year-long game development project. Students are only eligible for the capstone after having completed all the required courses as well as the required three ITP elective units. The capstone must be taken in both the fall and spring semesters of a single academic year.

Requirements for completion (four core courses plus 6 units of electives)

Minimum units: 19

Core courses (13 units)		units
ITP 165x*	Introduction to C++ Programming	2
ITP 365x*	Managing Data in C++	3
ITP 380	Video Game Programming	4
ITP 485	Programming Game Engines	4
Elective courses (6 units — 3 units must be ITP)		units
ITP 382x	Mobile Game Programming	3
ITP 435x	Professional C++	3
ITP 438x	Graphics Shader Programming	3
ITP 484x	Multiplayer Game Programming	3
CSCI 491abL**	Final Game Project	4-2

* ITP 165x and ITP 365x can be waived for students who have taken CSCI 103 and CSCI 104. However, these

students must take an additional elective course in order to have the appropriate number of upper-division units.

*** Optional capstone. See details above for requirements.*

Minor in Web Technologies and Applications

The Web technologies and application minor is designed to introduce students to the Web publishing and development fields. Upon completion of the minor, students will be able to design and develop Websites using major Web technologies, standards and applications. Students can use the theoretical concepts and practical applications of Web technologies not only in the Web industry, but also within a different major field of study. The broad areas of study include Web publishing, Web programming, databases and multimedia. Electives will be chosen based on the students' academic and professional goals.

Students should meet the regular admissions standards and have a declared USC major.

Requirements for completion (four core courses plus two electives)

Minimum units: 18

Core courses (13 units)		Units
ITP 104x	Web Publishing	2
ITP 300x	Database Web Development	3
ITP 301Lx	Interactive Web Development	4
ITP 460x	Web Application Project	4
Elective (two courses)		**Units**
ITP 302x	Advanced Web Publishing	2
ITP 310x	Design for User Experience	3
ITP 404x	Modern Technologies of Web Development	3
ITP 411x	Multimedia and Video Production	3
ITP 425x	Web Application Security	4
ITP 470x	Information Technology Practicum	3

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.

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.

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 101x Introduction to Information Technology (4, FaSp) 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 104Lx Web Publishing (2) Web publishing using HTML, CSS and other Web technologies. Concepts and theory of Web site creation, page layout and production. Introduction to advanced topics. Not available for major credit in electrical engineering or computer science.

ITP 105x Introduction to Computer Technologies and Applications (2) 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, FaSp) Introduction to object-oriented software design for business problems. Creation of console applications, windowed applications, and interactive Web applets. Not available for major credit in electrical engineering or computer science.

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 111x Introduction to Cloud Technologies (2) Introduction to the fundamentals of cloud computing; cloud security, storage, services, and networking options.

ITP 115 Programming in Python (2, FaSp) Python's high level data structures and clear syntax make it an ideal first language with powerful applications to science, business, finance, math, and the web.

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 140 Mobile Application Technologies (2, FaSp) Technologies, devices, operating systems, and tools of mobile applications, as well as the mobile industry. Students will use tools to create apps for different mobile devices.

ITP 165x Introduction to C++ Programming (2, FaSp) *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) *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. Recommended preparation: MATH 118x or MATH 125.*

ITP 204x Coding I: Web Publishing and Programming (4) Introduction to the fundamentals of programming through the lens of interactive websites. Covers both HTML/CSS layout as well as the JavaScript programming language.

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 214x Coding II: Electronic Prototyping (4) *Fundamentals of creating electronic prototypes. Covers both software (including Python, object-oriented programming, and Linux) as well as hardware (including electrical theory and hardware design). Prerequisite: ITP 204.*

ITP 215Lx 3-D Modeling, Animation, and Special Effects (2, FaSp) *Developing a 3-D animation from modeling to rendering: Basics of surfacing, lighting, animation and modeling techniques. Advanced topics: compositing, particle systems, and character animation. 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 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. Not available for major credit in electrical engineering.

ITP 260x Internet Technologies (4) 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, Fa) *Fundamental theory and technologies for creating dynamic, database-driven Websites: Structured Query Language. Prerequisite: ITP 104x; Recommended preparation: ITP 204x.*

ITP 301Lx Interactive Web Development (4, Sp) *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 302x Advanced Web Publishing (2) *Advanced topics in Web Publishing including HTML5, CSS3, and jQuery. Concept and theory of responsive design. Miscellaneous Webmaster topics including analytics, podcasting and search engine optimization. Prerequisite: ITP 104x.*

ITP 304L Technologies for Building Online Political Campaigns (4) 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 310x Design for User Experience (3) Fundamental concepts, techniques, practices, workflows, and tools associated with the practice of user experience and interaction design in web and mobile applications.

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 320x Enterprise Wide Information Systems (4, FaSp) The role Information Systems play in an

organization. Integration of Business Processes by using Enterprise Resource Planning Systems (ERP).

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 335x Computer Graphics and Animation Scripting (4) *Applications of the Python programming language to create tools for computer graphics and animation. Topics include linear algebra for graphics, exporters, and procedural asset generation. Prerequisite: ITP 214.*

ITP 340x Mobile App Design (3) *Fundamental concepts, techniques, practices, workflows, and tools associated with the practice of user experience design for mobile apps. Prerequisite: ITP 140.*

ITP 341x App Development for Phones and Tablets (3) *Develop phone and tablet applications for open-source platforms such as Android that utilize the core functionality of mobile devices such as GPS, accelerometers, touch gestures. Prerequisite: CSCI 104L, ITP 365x or ITP 367x.*

ITP 342 Mobile Application Development (3) *Develop applications for mobile devices such as iPhones and iPads (iOS) and other smart phones (Android). Build a mobile application from start to finish. Prerequisite: CSCI 104 or ITP 365x or ITP 367x.*

ITP 343 Mobile Development for Content and Media (1) *Creating media-focused mobile applications. Topics include recording/playback, audio synthesis, stream mixing, and positional audio. Corequisite: ITP 342.*

ITP 344x Advanced Topics in Mobile App Development (3) *Advanced topics in mobile app development such as using REST services, security, cloud integration, NFC (near field communication), wireless networking for mobile apps, monetizing apps, and the latest frameworks to create advanced apps. Prerequisite: ITP 342L.*

ITP 357x Enterprise Network Design (3) *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) *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 365x Managing Data in C++ (3) *Overview of basic data structures and algorithms including linked lists, stacks, queues, binary trees, and hash tables. Prerequisite: ITP 109x or ITP 115x or ITP 165x.*

ITP 367x Advanced Coding (4) *Accelerated introduction to the C++ programming language. Advanced programming concepts including memory allocation, data structures, and the Standard Template Library. Prerequisite: ITP 214.*

ITP 368x Programming Graphical User Interfaces (3) *Programming applications with dynamic graphical user interfaces. Topics include events, controls, resources, data bindings, styles, and user experience. Prerequisite: CSCI 104 or ITP 365.*

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 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 104L or ITP 365x.*

ITP 382x Mobile Game Programming (3) *Concepts and techniques required to develop games for smartphones and tablets. Topics include sprites, collision detection, mobile input, artificial intelligence, and augmented reality games. Prerequisite: CSCI 104L or ITP 365x.*

ITP 383 Database Systems: Concepts, Design and Implementation (3, Sp) (Enroll in ISE 382)

ITP 385x IT Consulting and Professional Services (3) *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 387x Cloud Architecture and Applications (4) *Survey of "Infrastructure as a Service"; and online application development. Concepts include online storage, computation, virtualization, messaging, and monetization. Prerequisite: CSCI 104 or ITP 365x or ITP 367x.*

ITP 391abx Video Game Project Management (4-2) *a: Project management basics for the video game industry, focusing on external development. Examine the role of the producer, managing development and coordinating with various stakeholders. Prerequisite: ITP 280. b: Project management for the video game industry, focusing on internal development. Creating ROIs, P&Ls, managing internal creative personnel, and coordinating with internal and external stakeholders.*

ITP 393x Video Game Design Documents (2) *Creation of design documents, from treatment to Game Design Document (GDD). Structuring documents for ease of use by team members who will create the game. Prerequisite: ITP 280.*

ITP 404x Modern Technologies of Web Development (3, Fa) *Provide students with the necessary skills to build web applications using modern techniques, frameworks, libraries, and tools that are used among developers within the industry. Prerequisite: ITP 301Lx or CSCI 351.*

ITP 405x Professional Applications and Frameworks in Web Development (3) *Provide students with the necessary skills to build structured, maintainable, scalable, and testable web applications using frameworks, tools, and techniques common in the industry. Prerequisite: CSCI 351 or ITP 300.*

ITP 411x Multimedia and Video Production (3, FaSp) *Visual communication and storytelling are essential skills, especially in the digital age. Overview of techniques and software to create, edit, and deliver compelling images and video. Not available for major credit in Engineering.*

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 415x 3-D Design and Prototyping (2) Explore the range of 3-D printing and prototyping technologies, and their application in modern industrial, design, and creative fields.

ITP 421x Advanced Programming for Enterprise Information Systems (3) *Object Oriented Programming for Enterprise information systems. Working with classes, objects, database tables, SQL. Designing reports and Graphical user interfaces. Leveraging service oriented architecture. Not available for credit for engineering majors. Prerequisite: ITP 320x; recommended preparation: object oriented programming.*

ITP 422L Configuring Enterprise Resource Planning Systems (3) *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) *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 435x Professional C++ (3, Sp) *Applications of advanced concepts in C++ including lambda expressions, template metaprogramming, secure coding, parallel programming techniques, and the boost library. Prerequisite: CSCI 104L or ITP 365x.*

ITP 437x Secure Programming (3) *Practical techniques for prevention, assessment, and resolution of security vulnerabilities in software. Prerequisite: CSCI 104 or ITP 365x.*

ITP 438x Graphics Shader Programming (3, Fa) *Implementation of advanced graphical effects with shaders in a production environment. Topics include math for shaders, lighting, mapping techniques, procedural generation, and global illumination. Prerequisite: ITP 165x.*

ITP 439x Compiler Development (3) *Practical applications of techniques used to develop a programming language compiler. Prerequisite: ITP 435x.*

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 442x Mobile App Project (4) *Capstone course for Mobile App Development minor. Work in project teams to develop new mobile app from start to finish. Meet with client, create app design, develop, test, and demonstrate app to client. Prerequisite: ITP 140.*

ITP 444 Social Game Development Workshop (2) *Hands-on development of video games for social media; realities of the social games market; development tools and processes. Prerequisite: ITP 101.*

ITP 445 Macintosh, OSX, and iOS Forensics (3) *Digital forensics. Digital evidence. Apple. Mac. Macintosh. OSX. iOS. iPhone. iPad. Prerequisite: ITP 375x.*

ITP 446 Cyber Breach Investigations (3, Fa) *Cyber breaches. Data theft. Enterprise data analysis. Network forensic analysis. Server forensics. Prerequisite: ITP 375.*

ITP 447 Mobile Device Security and Forensics (3, Sp) *Mobile device security. Mobile device forensics. Android. Blackberry. Windows phone. Symbian. Prerequisite: ITP 375x.*

ITP 448 Cyber Litigation Support (3, Sp) *Civil Litigation. Digital and Electronic Evidence. Electronic Discovery. eDiscovery. Electronically Stored Information. Prerequisite: ITP 375x.*

ITP 454x Enterprise Resource Planning, Design, and Implementation (3) *Process and requirements to implement an Enterprise Resource Planning System (ERP). Set up server, implement ERP system, then transfer and configure database for case company. Not for major credit for Electrical Engineering students. Prerequisite: ITP 320x.*

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) *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, Sp) *Skills to plan, analyze, build, and launch professional Web sites with actual clients. Includes project management, documentation, technology assessment, security, UI, Q/A, and various methodologies. Recommended preparation: One 300-level Web minor course.*

ITP 466 Building the High Tech Startup (4) Teach students the basic technologies and processes involved in building web and mobile startups. Students will be introduced to the different aspects of building a web startup including online business models, Product management, Agile development processes, technology platforms and operations, customer development and online marketing.

ITP 470x Information Technology Practicum (1-4, max 8, FaSpSm) *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 476 Technologies for Interactive Marketing (4) Designed to introduce students to technologies, concepts and strategies in the emerging online advertising ecosystem. Through lectures, discussions, and projects, students learn strategies and tactics to drive traffic to a website. They learn how to analyze and measure the efficacy of their plans. Lastly, they will work with a real client and with a real budget to craft and execute an online marketing plan.

ITP 479 Cyber Law and Privacy (3) Cyber legal issues, search and seizure, 4th amendment and digital evidence, private searches, case law relating to search and seizure.

ITP 480x Information Technology Internship (1-4, max 8) *Practical experience in applying information technology skills in real-world settings. Supervised internship at companies and start-ups. Balancing academic rigor with corporate challenges and deadlines. Not available for graduate credit. Graded*

CR/NC. Recommended preparation: knowledge of chosen function area.

ITP 482 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: CSCI 101L or IOM 435 or ISE 382.*

ITP 484x Multiplayer Game Programming (3) *Techniques for developing networked multiplayer games. Topics include Internet protocols, network topology, data streams, object sharing, client prediction, latency, and back-end databases. Prerequisite: ITP 380.*

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: ITP 380.*

ITP 486 Securing and Auditing Enterprise Resource Planning Systems (3) *Management and technical issues related to the security of ERP systems. Students will audit ERP systems and apply appropriate security controls. Prerequisite: ITP 320x.*

ITP 487 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. Prerequisite: ITP 320x.*

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 except toward undergraduate and graduate programs offered by the Epstein Department of Industrial and Systems Engineering. Prerequisite: ITP 320x.*

ITP 489 In-Memory Database Systems for Real Time Analytics (3) *Examines the design, architecture, and capabilities of in-memory database and their application to real-time analytics. Prerequisite: ITP 320x or ITP 482.*

ITP 491x Level Design and Development for Video Games (4) *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. Not for major credit for computer science and electrical engineering students. Prerequisite: ITP 280.*

ITP 496 The Startup Launchpad Lab (2) *A real world, hands-on learning experience on what it's like to actually start a high-tech company. Students will work in teams to design, prototype and implement version 1.0 of a high tech web or mobile startup. Prerequisite: BAEP 451, BAEP 452, ITP 466 and ITP 476; corequisite: BAEP 496.*

ITP 499x Special Topics (2-4, max 8) Recent developments in computers and data processing.

ITP 555 Functionality of Enterprise Resource Planning Systems (1) *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
Gerontology Center 240
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Email: isedept@usc.edu

Program Director: B. Khoshnevis, Ph.D.

Master of Science in Manufacturing Engineering

Manufacturing engineering at USC is a multidisciplinary program that confers the degree of Master of Science and is designed to produce graduates capable of responding to the needs of modern, up-to-date manufacturing. These graduates should be able to design, install and operate complex manufacturing systems made up of people, materials, automated machines and information systems. The Departments of Computer Science, Electrical Engineering, Industrial and Systems Engineering, Materials Science, Mechanical Engineering, and Entrepreneurship participate in the Manufacturing Engineering Program.

Course work in the program will train students in traditional manufacturing engineering topics, such as materials selection and process design. Additional courses will include the more modern, system-level concepts of integrated product and process design, applications of modern information technology to design and manufacturing, hands-on laboratories using advanced manufacturing equipment and commercial software, and entrepreneurship.

Curriculum

A total of 30 units is required beyond the B.S. degree. A minimum of 21 units must be at the 500 level or above. A maximum of 6 units of electives may be taken from non-engineering departments. At least three courses must be taken in the student's selected area of specialization.

Required courses		Units
CSCI 585	Database Systems, or	
ISE 510	Advanced Computational Design and Manufacturing	3
ISE 511L	Mechatronic Systems Engineering	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.

Product Development Engineering

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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 (MS PDE) 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 146 verbal and 151 quantitative.

The MS PDE 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 adviser 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 460	Engineering Economy	3
ISE 470	Human/Computer Interface Design	3
ISE 511L	Mechatronics Systems Engineering	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	Performance Modeling and 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 506	Design of Low Cost Space Missions	3
AME 527	Elements of Vehicle and Energy Systems 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
Adviser-approved electives	
(Must be upper-division 400- or 500-level courses; up to 4 units can be transferred from other institutions)	
Total units required for degree	27

Sustainable Infrastructure Systems

The Sustainable Infrastructure Systems program prepares students for immediate and effective participation in the modern infrastructure workforce through a common core that includes smart-system design for sustainable infrastructures, the societal and regulatory context of infrastructure engineering decisions, and construction management. Five plans of study for the Master of Science degree allow for specialization based on background and interest.

Master of Science in Civil Engineering (Transportation Systems)

Required Courses		Units
CE 471	Principles of Transportation Engineering	3
CE 501	Functions of the Constructor	3
CE 515	Sustainable Infrastructure Systems	3
CE 579	Introduction to Transportation Planning Law	3
PPD 633	Urban Transportation Planning and Management	4

Elective Courses (Four Courses, Other Electives Upon Approval*)		Units
CE 583	Design of Transportation Facilities	3
CE 585	Traffic Engineering and Control	3
CE 588	Railroad Engineering	3
CE 589	Port Engineering: Planning and Operations	3
PPD 634	Institutional and Policy Issues in Transportation	4
PPD 692	Transportation and the Environment	4

Note: Students electing the Master of Science in Civil Engineering (Transportation Systems) degree option are expected to have a background in statistics and uncertainty equivalent to ISE 225 or CE 408, and engineering economy equivalent to ISE 460. Admitted students who do not meet these prerequisites can satisfy the requirements by taking appropriate, adviser-approved electives.

Master of Science in Civil Engineering (Water and Waste Management)

Required Courses		Units
CE 451	Water Resources Engineering	3
CE 453	Water Quality Control	3
CE 476	Design of Pressurized Hydraulic Systems	3
CE 501	Functions of the Constructor	3
CE 515	Sustainable Infrastructure Systems	3

Elective Courses (Four Courses, Other Electives with Approval*)		Units
CE 504	Solid Waste Management	3
CE 510	Groundwater Management	3
CE 511	Flood Control Hydrology	3

| CE 516 | Geohydrology | 3 |
| CE 520a | Ocean and Coastal Engineering | 3 |

* Note: Students electing the Master of Science in Civil Engineering (Water and Waste Management) degree option are expected to have a background in fluid mechanics equivalent to CE 309 or ENE 410. Admitted students who do not meet this prerequisite will be assigned a course to complete the deficiency.

Master of Science in Electrical Engineering (Electric Power)

Required Courses		Units
CE 515	Sustainable Infrastructure Systems	3
EE 443	Introduction to Power Systems	3
EE 444	Power Systems Technology	3
EE 521	Power Systems Analysis and Design	3

Elective Courses (Five Courses, TAKE AT LEAST ONE FROM EACH AREA)		Units
Transmission, Distribution and Planning		
CE 501	Functions of the Constructor	3
EE 516	High-Voltage DC Transmission Systems	3
EE 524	Transients in Power Systems	3
EE 525	Power System Protection	3
EE 526	Renewable Energy in Power Systems	3
High-Voltage Equipment and Design		
EE 515	High-Voltage Technology	3
EE 528	Power Electronics	3
Power-System Control and the Smart Grid		
EE 482	Linear Control Systems	3
EE 527	Net-Centric Power-System Control	3
EE 543a	Digital Control Systems	3
EE 585	Linear System Theory	3
EE 593	Multivariable Control	3

Required Courses (7 courses, 21 units)		Units
AME 430	Thermal Systems Design	3
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3
AME 577	Survey of Energy and Power for a Sustainable Future	3
AME 578	Modern Alternative Energy Conversion Devices	3
CE 501	Functions of the Constructor	3
CE 515	Sustainable Infrastructure Systems	3

Elective Courses (Two Courses, 6 units*)		Units
AME 513	Principles of Combustion	3
AME 514	Applications of Combustion and Reacting Flows	3
AME 579	Combustion Chemistry and Physics	3
AME 581	Introduction to Nuclear Engineering	3
AME 582	Nuclear Reactor Physics	3
ENE 505	Energy and the Environment	3
Transmission, Distribution and Planning		
CE 501	Functions of the Constructor	3
EE 516	High-Voltage DC Transmission Systems	3
EE 524	Transients in Power Systems	3
EE 525	Power System Protection	3

EE 526	Renewable Energy in Power Systems	3
High-Voltage Equipment and Design		
EE 515	High-Voltage Technology	3
EE 528	Power Electronics	3
Power-System Control and the Smart Grid		
EE 482	Linear Control Systems	3
EE 527	Net-Centric Power-System Control	3
EE 543a	Digital Control Systems	3
EE 585	Linear System Theory	3
EE 593	Multivariable Control	3

Master of Science in Mechanical Engineering (Energy Conversion)

Required Courses (7 courses, 21 units)		Units
AME 430	Thermal Systems Design	3
AME 525	Engineering Analysis	3
AME 526	Engineering Analytical Methods	3
AME 577	Survey of Energy and Power for a Sustainable Future	3
AME 578	Modern Alternative Energy Conversion Devices	3
CE 501	Functions of the Constructor	3
CE 515	Sustainable Infrastructure Systems	3

Elective Courses (Two Courses, 6 units*)		Units
AME 513	Principles of Combustion	3
AME 514	Applications of Combustion and Reacting Flows	3
AME 579	Combustion Chemistry and Physics	3
AME 581	Introduction to Nuclear Engineering	3
AME 582	Nuclear Reactor Physics	3
ENE 505	Energy and the Environment	3

* Students are encouraged to consider electives from other Sustainable Infrastructure Systems programs

Students with M.S. degrees in engineering or science disciplines can be accepted in these programs. Students must satisfy all other departmental degree requirements.

Systems Architecting and Engineering

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Faculty

IBM Chair in Engineering Management: F. Stan Settles, Ph.D. (Astronautical Engineering, Industrial and Systems Engineering)

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

Gordon S. Marshall Professor of Engineering Technology: Roger Ghanem, Ph.D. (Aerospace and Mechanical Engineering, Civil and Environmental Engineering)

TRW Professor of Software Engineering: Barry Boehm, Ph.D. (Computer Science, Industrial and Systems Engineering)

Professors: Barry Boehm, Ph.D. (Computer Science, Industrial and Systems Engineering); John Choma, Ph.D. (Electrical Engineering)*; Daniel Erwin, Ph.D. (Aerospace and Mechanical Engineering, Astronautical Engineering)*; Roger Ghanem, Ph.D. (Aerospace and Mechanical Engineering, Civil and Environmental Engineering); Mike Gruntman, Ph.D. (Aerospace and Mechanical Engineering, Astronautical Engineering); Petros Ioannou, Ph.D. (Electrical Engineering); Yan Jin, Ph.D. (Aerospace and Mechanical Engineering); Behrokh Khoshnevis, Ph.D. (Aerospace and Mechanical Engineering, Civil and Environmental Engineering, Industrial and Systems Engineering); Stephen C-Y Lu, Ph.D. (Computer Science, Aerospace and Mechanical Engineering, Industrial and Systems Engineering); James E. Moore, II, Ph.D. (Civil and Environmental Engineering, Industrial and Systems Engineering, Public Policy); F. Stan Settles, Ph.D. (Astronautical Engineering, Industrial and Systems Engineering); Cyrus Shahabi, Ph.D. (Computer Science); Firdaus E. Udwadia, Ph.D. (Aerospace and Mechanical Engineering, Civil and Environmental Engineering, Data Science and Operations, Mathematics)

Assistant Professor: Ketan Savla, Ph.D. (Civil and Environmental Engineering)

Professors of Engineering Practice: George Friedman, Ph.D. (Astronautical Engineering); Azad M. Madni, Ph.D. (Astronautical Engineering)

Research Professor: Elliot Axelband, Ph.D.

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

Honor Societies

Omega Alpha Association

Omega Alpha Association is the systems engineering honor society. The adviser 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:

- a total of at least 30 units is required, consisting of at least three units in the technical management area, three units in the general technical area, and 9 units in the technical specialization area;

- 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;

- 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;

- at least 24 of the 30 units must be taken in the Viterbi School of Engineering;

- units to be transferred (maximum of four with adviser approval) must have been taken prior to taking classes at USC; interruption of residency is not allowed;

- no more than 6 units of Special Topics courses (499 or 599) may be counted for this degree;

- thesis and directed research registrations may be allowed to individual students only by special permission of the supervising faculty member and the program director;

- 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	
SAE 560	Economic Considerations for Systems Engineering	3
SAE 541	Systems Engineering Theory and Practice	3
SAE 542	Advanced Topics in Systems Engineering	3
SAE 547	Model-Based Systems Architecting and Engineering, or	
SAE 548	Systems/System-of-Systems Integration and Communication	3
SAE 549	Systems Architecting	3
Electives		**Units**
Adviser-approved electives in technical management area		3
Adviser-approved electives in general technical area		3
Adviser-approved electives in technical specialization area		9

Technical Management Area: Take one course (3 units) from the following:

CE 556	**Project Controls-Budgeting and Estimating**	**3**
DSO 525*	Quality Improvement Methods	3
DSO 527*	Managerial Decision Analysis	3
DSO 537*	Global Businesses and Markets: Strategies Enabled by Technology	3
DSO 580*	Project Management	3
ISE 515	Engineering Project 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. DSO 525 and DSO 527 are offered irregularly.

General Technical Area: Take one course (3 units) from the following:

CSCI 510	**Software Management and Economics**	**3**
CSCI 577ab	Software Engineering	4-4
ISE 580	Performance Modeling and Simulation	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: Nine 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 521, AME 532a, AME 544, AME 548, AME 560, AME 588

Artificial Intelligence/Neural Networks: CSCI 460, CSCI 545, CSCI 561, CSCI 564, 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 556, CE 583

Engineering Management Systems: ISE 515, ISE 530, ISE 535, ISE 544, ISE 562, ISE 580, ISE 585, SAE 550

Integrated Media Systems: EE 450, EE 522, EE 555, EE 569, EE 596; 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

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 five		units
ISE 460	Engineering Economy, 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 547	Model-Based Systems Architecting and Engineering	3
SAE 548	Systems/System-of-Systems Integration and Communication	3
SAE 549	Systems Architecting	3
SAE 574	Net-Centric Systems Architecting and Engineering	3

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

Computer Science Emphasis

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	Probabilistic Reasoning	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 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 666	Data Communication	3
		15

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, FaSpSm) 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.*

SAE 547 Model-Based Systems Architecting and Engineering (3) *Approaches for modeling systems using software such as SySML; modeling system, requirements, structure, behavior, and parametrics; mapping to hardware description language and behavioral code generation. Recommended preparation:* Modeling and simulation courses.

SAE 548 Systems/System-of-Systems Integration and Communication (3, FaSp) *Essentials of systems and system-of-systems integration from the perspectives of business, programs, and technology. Process, legacy, and systems-of-systems integration. Verification and validation methods. Case studies. Recommended preparation:* bachelor's degree in engineering or physical sciences.

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, Sp) 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.