A Message from the Dean

Since it welcomed its first engineering students more than 65 years ago, the UCLA Henry Samueli School of Engineering and Applied Science has been at the forefront of advanced interdisciplinary research. Among its notable achievements, the school is well-known as the birthplace of the Internet, for developing the first reverse-osmosis membrane for the desalination of water, and for many other activities that have led to new technologies and changed the way we interact with the world around us.

Our faculty members and students are leaders in new frontiers of applied science and engineering research, in emerging areas such as clean and renewable energy, clean water technology, personalized healthcare, wireless sensing and sensor systems, cybersecurity, information technology, bioengineering, nanomanufacturing, microelectromechanical and nanoelectromechanical systems, and nanoelectronics.

UCLA Engineering is ideally situated to engage in interdisciplinary research and educational initiatives with others on campus and across Southern California. It benefits from proximity to the world-renowned David Geffen School of Medicine and the John E. Anderson Graduate School of Management, as well as the Los Angeles entertainment and media industries, Silicon Valley, the defense and aerospace industries, and a growing biotechnology sector.

Our curriculum—with its emphasis on breadth of knowledge as well as depth—prepares our students for success in meeting the ever-changing demands of the engineering profession. In addition, undergraduate student research opportunities are widely available, and we encourage our students to take advantage of them.

Students may choose to work with individual faculty members or to participate in any of the school’s world-class interdisciplinary research centers. These include the NSF Center for Embedded Networked Sensing, Center on Functional Engineered Nano Architectonics, NRI Western Institute of Nanoelectronics, DOE-funded Center for Molecularly Engineered Energy Materials, NSF Center for Domain-Specific Computing, Smart Grid Energy Research Center, Wireless Health Institute, and Named Data Networking Project. We encourage students to spend one summer as interns in industry. Our faculty members and students are also active partners in the California NanoSystems Institute located at UCLA. In addition, the school is developing its research breakthroughs into the commercial sector through the off-campus Institute for Technology Advancement (ITA).

Our distinguished faculty is composed of recognized experts in their fields, including 23 members of the National Academy of Engineering, and many junior faculty who are widely acclaimed for their work. Many faculty members are award-winning educators, and every faculty member, no matter how senior, teaches at least one undergraduate course each year.

UCLA Engineering is also committed deeply to public service. This includes translating research discoveries made here into applications and innovations that benefit the state and nation. It also includes partnerships in the community and with K-12 schools to inspire more young people to take an interest in science and engineering careers.

The UCLA Henry Samueli School of Engineering and Applied Science is seeking exceptional and dedicated students who share our desire to positively contribute to the engineering profession and society. I invite you to consider becoming a UCLA engineer.

Vijay K. Dhir
Dean
UCLA Henry Samueli School of Engineering and Applied Science
UCLA
HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE 2012-13

ANNOUNCEMENT
OCTOBER 1, 2012
UNIVERSITY OF CALIFORNIA, LOS ANGELES
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TO ALL STUDENTS:

Pursuant to the Federal Family Educational Rights and Privacy Act (FERPA), the California Information Practices Act, and the University of California Policies Applying to the Disclosure of Information from Student Records, students at UCLA have the right to (1) inspect and review records pertaining to themselves in their capacity as students, except as the right may be waived or qualified under federal and state laws and University policies, (2) have withheld disclosure, absent their prior written consent for release, personally identifiable information from their student records, except as provided by federal and state laws and University policies, (3) inspect records maintained by UCLA of disclosures of personally identifiable information from their student records, (4) seek correction of their student records through a request to amend the records or, if such request is denied, through a hearing, and (5) file complaints with the U.S. Department of Education regarding alleged violations of the rights accorded them by FERPA.

UCLA, in accordance with federal and state laws and University policies, has designated the following categories of personally identifiable information as “public information” that UCLA may release and publish without the student’s prior consent: name, address (local mailing, permanent, and/or e-mail), telephone numbers, major field of study, dates of attendance, enrollment status, grade level, number of course units in which enrolled, degrees and honors received, the most recent previous educational institution attended, participation in officially recognized activities (including intercollegiate athletics), and the name, weight, and height of participants on intercollegiate athletic teams.

As a matter of practice, UCLA does not publish student addresses or telephone numbers in the campus electronic directory unless released by the student. The term “public information” in this policy is synonymous with the term “directory information” in FERPA.

Students who do not wish certain items (i.e., name, local mailing, permanent, and/or e-mail address, telephone numbers, major field of study, dates of attendance, number of course units in which enrolled, and degrees and honors received) of this “public information” released and published may so indicate through a UCLA FERPA Restriction Request form available from the Registrar’s Office, 1113 Murphy Hall. Students records that are the subject of federal and state laws and University policies may be maintained in a variety of offices, including the Registrar’s Office, Office of the Dean of Students, UCLA Career Center, Graduate Division, UCLA External Affairs Department, and the offices of a student’s College or school and major department. Students are referred to the online UCLA Campus Directory (http://directory.ucla.edu) which lists all the offices that may maintain student records, together with their campus address and telephone number. Students have the right to inspect their student records in any such office subject to the terms of federal and state laws and University policies. Inspection of student records maintained by the Registrar’s Office is by appointment only and must be arranged three working days in advance. Call (310) 825-1091, option 6, or inquire at the Registrar’s Office, 1113 Murphy Hall.

A copy of the federal and state laws, University policies, and the print UCLA Telephone Directory may be inspected in the office of the Information Practices Coordinator, 500 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of the Dean of Students, 1206 Murphy Hall.

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All announcements herein are subject to revision. Every effort has been made to ensure the accuracy of the information presented in the Announcement of the UCLA Henry Samueli School of Engineering and Applied Science. However, all courses, course descriptions, instructor designations, curricular degree requirements, and fees described herein are subject to change or deletion without notice. Further details on graduate programs are available in various Graduate Division publications which are available online at http://grad.ucla.edu.
Henry Samueli School of Engineering and Applied Science

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Jenn-Ming Yang, Ph.D., Professor and Chair, Materials Science and Engineering Department

The Campus
UCLA is a large urban university situated between the city and the sea at the foot of the Santa Monica Mountains. Less than six miles from the Pacific, it is bordered by Sunset and Wilshire Boulevards. As the city has grown physically and culturally, so has the campus, whose students and faculty mirror the cultural and racial diversity of today’s Los Angeles. UCLA is one of the most widely respected and recognized universities in the world, and its impact on society can be felt into the far reaches of the globe. Students come from around the world to receive a UCLA education, and our alumni go on to become leaders in their fields, from elected officials to heads of international corporations.

UCLA is recognized as the West’s leading center for the arts, culture, and medical research. Each year, more than half a million people attend visual and performing arts programs on campus, while more than 300,000 patients from around the world come to the Ronald Reagan UCLA Medical Center for treatment. The university’s 419-acre campus houses the College of Letters and Science and 11 professional schools. There are more than 40,600 students enrolled in 129 undergraduate and 197 graduate degree programs. Nearly one in every 140 Californians holds a UCLA degree.

UCLA is rated one of the best public research universities in the U.S. and among a handful of top U.S. research universities, public and private. The chief executive of the University is Chancellor Gene D. Block. He oversees all aspects of the University’s three-part mission of education, research, and service.

Southern California has grown to become one of the nation’s dominant industrial centers, and the UCLA Henry Samueli School of Engineering and Applied Science (HSSEAS) is uniquely situated as a hub of engineering research and professional training for this region.

The School
The UCLA College of Engineering (as it was known then) was established in 1943 when California Governor Earl Warren signed a bill to provide instruction in engineering at the UCLA campus. It welcomed its first students in 1945 and was dedicated as the Henry Samueli School of Engineering and Applied Science in 2000. The school ranks among the top 10 engineering schools in public universities nationwide.

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Center for Embedded Networked Sensing (CENS) develops embedded networked sensing systems and applies this revolutionary technology to critical scientific and social applications. The Center on Functional Engineered Nano Architectonics (FENA) leverages the latest advances in nanotechnology, molecular electronics, and quantum computing to extend semiconductor technology further into the realm of the nanoscale. The West- ern Institute of Nanoelectronics (WIN), among the world’s largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically needed innovations in semiconductor technology. The Center for Molecularly Engineered Energy Materials (MEEM) focuses on the creation and production of nanoscale materials for use in converting solar energy into electricity and electrical energy storage, and capturing and separating greenhouse gases. The Center for Domain-Specific Computing (CDSC) is developing high-performance, energy efficient, customizable computing that could revolutionize the way computers are used in healthcare and other important applications. The Smart Grid Energy Research Center (SMERC) conducts research, creates innovations, and demonstrates advanced wireless/communications, Internet, and sensor-and-control technologies to enable the development of the next generation of the electric utility grid. The Wireless Health Institute (WHI) is a community of UCLA experts and innovators from a variety of disciplines dedicated to improving healthcare delivery through the development and application of wireless network-enabled technologies integrated with current and next-generation medical enterprise computing. The Named Data Networking (NDN) Project is investigating the future of the Internet’s architecture, capitalizing on its strengths and addressing weaknesses, to accommodate emerging patterns of communication. Finally, the California NanoSystems Institute (CNSI)—a joint endeavor with UC Santa Barbara—develops the information, biomedical, and manufacturing technologies of the twenty-first century.

In addition, the school has identified critical areas for collaborative research that will have a major impact on the future of California and the world. Among these are biomedical informatics; alternative energy solutions; secure electronic transfer of information; new tools for the entertainment industry; systems, dynamics, and controls; advanced technologies for water reclamation; and new approaches and technologies for aerospace engineering.

And the school recently established the Institute for Technology Advancement (ITA), an off-campus institute dedicated to the effective transition of high-impact innovative research from UCLA to product development and commercialization. ITA nurtures and incubates breakthrough ideas to create new industrial products, as well as provides a learning platform for faculty members and students to engage in transitional technology research.

The school offers 29 academic and professional degree programs. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical
Engineering, Civil Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering. The undergraduate curricula leading to these degrees provide students with a solid foundation in engineering and applied science and prepare graduates for immediate practice of the profession as well as advanced studies. In addition to engineering courses, students complete about one year of study in the humanities, social sciences, and/or fine arts.

Master of Science and Ph.D. degrees are offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Manufacturing Engineering (M.S. only), Materials Science and Engineering, and Mechanical Engineering. A school-wide online Master of Science in Engineering degree program is also offered. The Engineer degree is a more advanced degree than the M.S. but does not require the research effort and orientation involved in a Ph.D. dissertation. For information on the Engineer degree, see Graduate Programs on page 23. A one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science.

Endowed Chairs

Endowed professorships or chairs, funded by gifts from individuals or corporations, support the research and educational activities of distinguished members of the faculty. The following endowed chairs have been established in the Henry Samueli School of Engineering and Applied Science.

L. M. K. Boelter Chair in Engineering

Tauraott and Dorothea Frederking Endowed Chair in Cryogenics

Norman E. Friedmann Chair in Knowledge Sciences

Leonard Kleinrock Chair in Computer Science

Evelyn Knight Chair in Engineering

Levi James Knight, Jr., Chair in Engineering

Richard G. Newman AECOM Endowed Chair in Civil Engineering

Nippon Sheet Glass Company Chair in Materials Science

Northrop Grumman Chair in Electrical Engineering

Northrop Grumman Chair in Electrical Engineering/Electromagnetics

Northrop Grumman Opto-Electronic Chair in Electrical Engineering

Ralph M. Parsons Foundation Chair in Chemical Engineering

Jonathan B. Postel Chair in Computer Systems

Jonathan B. Postel Chair in Networking

Raytheon Company Chair in Electrical Engineering

Raytheon Company Chair in Manufacturing Engineering

Charles P. Reames Endowed Chair in Electrical Engineering

Edward K. and Linda L. Rice Endowed Chair in Materials Science

Ben Rich Lockheed Martin Chair in Aeronautics

Rockwell Collins Chair in Engineering

William Frederick Seyer Chair in Materials Electrochemistry

Ronald and Valerie Sugar Endowed Chair in Engineering

Symantec Chair in Computer Science

Carol and Lawrence E. Tannas, Jr., Endowed Chair in Engineering

William D. Van Vorst Chair in Chemical Engineering Education

Wintek Endowed Chair in Electrical Engineering

The Engineering Profession

The following describes the challenging types of work HSSEAS graduates might perform based on their program of study.

Aerospace Engineering

Aerospace engineers conceive, design, develop, test, and supervise the construction of aerospace vehicle systems such as commercial and military aircraft, helicopters and other types of rotorcraft, and space vehicles and satellites, including launch systems. They are employed by aerospace companies, airframe and engine manufacturers, government agencies such as NASA and the military services, and research and development organizations.

Working in a high-technology industry, aerospace engineers are generally well versed in applied mathematics and the fundamental engineering sciences, particularly fluid mechanics and thermodynamics, dynamics and control, and structural and solid mechanics. Aerospace vehicles are complex systems. Proper design and construction involves the coordinated application of technical disciplines, including aerodynamics, structural analysis and design, stability and control, aerelasticity, performance analysis, and propulsion systems technology.

Aerospace engineers use computer systems and programs extensively and should have at least an elementary understanding of modern electronics. They work in a challenging and highly technical atmosphere and are likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts.

The B.S. program in Aerospace Engineering emphasizes fundamental disciplines and therefore provides a solid base for professional career development in industry and graduate study in aerospace engineering. Graduate education prepares students for careers at the forefront of aerospace technology. The Ph.D. degree provides a strong background for employment by government laboratories, such as NASA, and industrial research laboratories supported by the major aerospace companies. It also provides the appropriate background for academic careers.

Bioengineering

At the interface of medical sciences, basic sciences, and engineering, bioengineering has emerged internationally as an established engineering discipline. As these disciplines converge in the twenty-first century, bioengineers solve problems in biology and medicine by applying principles of physical sciences and engineering while applying biological principles to create new engineering paradigms, such as biomimetic materials, DNA computing, and neural networking. The genomic and proteomic revolution will drive a new era in the bioengineering industry, and future bioengineers must combine proficiency in traditional engineering, basic sciences, and molecular sciences to function as effective leaders of multidisciplinary teams.

UCLA has a long history of fostering interdisciplinary training and is a superb environment for bioengineers. UCLA boasts the top hospital in the western U.S., nationally ranked medical and engineering schools, and numerous nationally recognized programs in basic sciences. Rigorously trained bioengineers are needed in research institutions, academia, and industry. Their careers may follow their bioengineering concentration (e.g., tissue engineering, bioMEMs, biointerfaces, image and signal processing, neuroengineering, cellular engineering, molecular engineering, biomechanics, nanofabrication, bioacoustics, biomaterials, etc.), but the ability of bioengineers to cut across traditional field boundaries will facilitate their innovation in new areas. For exam-
ple, a bioengineer with an emphasis in tissue engineering may begin a career by leading a team to engineer an anterior cruciate ligament for a large orthopedic company, and later join a research institute to investigate the effects of zero gravity on mechanical signal transduction pathways of bone cells.

**Chemical and Biomolecular Engineering**

Chemical and biomolecular engineers use their knowledge of mathematics, physics, chemistry, biology, and engineering to meet the needs of our technological society. They design, research, develop, operate, and manage within the biochemical and chemical industries and are leaders in the fields of energy and the environment, nanotechnology, systems engineering, biotechnology and biomolecular engineering, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, biotechnology, biofuel, food, aerospace, automotive, water treatment, and semiconductor industries. Architectural, engineering, and construction firms employ chemical engineers for equipment and process design. It is also their mission to develop the clean and environmentally friendly technologies of the future.

Major areas of fundamental interest within chemical engineering are:

1. **Applied chemical kinetics**, which involves the design of chemical and biochemical reaction processes and reactors,
2. **Transport phenomena**, which involves the exchange of momentum, heat, and mass in physical and biological systems and has applications to the separation of valuable materials from mixtures, or of pollutants from gas and liquid streams,
3. **Thermodynamics**, which is fundamental to physical, chemical, and biological processes, and
4. **Process design and synthesis**, which provide the overall framework and computing technology for integrating chemical engineering knowledge into industrial application and practice.

**Civil and Environmental Engineering**

Civil engineers plan, design, construct, and manage a range of physical systems, such as buildings, bridges, dams and tunnels, transportation systems, water and waste-water treatment systems, coastal and ocean engineering facilities, and environmental engineering projects, related to public works and private enterprises. Thus, civil and environmental engineering embraces activities in traditional areas and in emerging problem areas associated with modern industrial and social development.

The civil engineering profession demands rigorous scientific training and a capacity for creativity and growth into developing fields. In Southern California, besides employment in civil engineering firms and governmental agencies for public works, civil engineering graduates often choose the aerospace industry for assignments based on their structural engineering background. Graduates are also qualified for positions outside engineering where their broad engineering education is a valuable asset.

The curriculum leading to a B.S. in Civil Engineering provides an excellent foundation for entry into professional practice, as well as for graduate study in civil engineering and other related fields.

**Computer Science and Engineering**

Students specializing in the computer science and engineering undergraduate program are educated in a range of computer system concepts. As a result, students at the B.S. level are qualified for employment as applications programmers, systems programmers, digital system designers, digital system marketing engineers, and project engineers.

Undergraduates can major either in the computer science and engineering program or in the computer science program.

Graduate degree programs in computer science prepare students for leadership positions in the computer field. In addition, they prepare graduates to deal with the most difficult problems facing the computer science field. University or college teaching generally requires the graduate degree.

**Electrical Engineering**

The electrical engineering discipline deals primarily with the sensing, analysis, and processing of information. It develops circuits, devices, algorithms, and theories that can be used to sense data, analyze data, extrapolate data, communicate data, and take action in response to the data collected. The Electrical Engineering Department is a recognized leader in education and research related to these subjects.

**Manufacturing Engineering**

Manufacturing engineering is an interdisciplinary field that integrates the basic knowledge of materials, design, processes, computers, and system analysis. The manufacturing engineering program is part of the Mechanical and Aerospace Engineering Department.

Specialized areas are generally classified as manufacturing processes, manufacturing planning and control, and computer-aided manufacturing.

Manufacturing engineering as an engineering specialty requires the education and experience necessary to understand, apply, and control engineering procedures in manufacturing processes and production methods of industrial commodities and products. It involves the generation of manufacturing systems, the development of novel and specialized equipment, research into the phenomena of fabricating technologies, and manufacturing feasibility of new products.

Coursework, independent studies, and research are offered in the manufacturing processes area, leading to an M.S. degree. This includes computer-aided design and computer-aided manufacturing, robotics, metal forming and metal cutting analysis, nondestructive evaluation, and design and optimization of manufacturing processes.

**Materials Engineering**

Materials engineering is concerned with the structure and properties of materials used in modern technology. Advances in technology are often limited by available materials. Solutions to energy problems depend largely on new materials, such as solar cells or materials for batteries for electric cars.

Two programs within materials engineering are available at UCLA:

1. In the **materials engineering** program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries. Materials engineers are responsible for the selection and testing of materials for specific applications. Traditional fields of metalurgy and ceramics have been merged in industry, and this program reflects the change.

2. In the **electronic materials option** of the materials engineering program, students learn the basics of materials engineering with a concentration in electronic materials and processing. The optional program requires addi-
Mechanical Engineering

Mechanical engineering is a broad discipline finding application in virtually all industries and manufactured products. The mechanical engineer applies principles of mechanics, dynamics, and energy transfer to the design, analysis, testing, and manufacture of consumer and industrial products. A mechanical engineer usually has specialized knowledge in areas such as design, materials, fluid dynamics, solid mechanics, heat transfer, thermodynamics, dynamics, control systems, manufacturing methods, and human factors. Applications of mechanical engineering include design of machines used in the manufacturing and processing industries, mechanical components of electronic and data processing equipment, engines and power-generating equipment, components and vehicles for land, sea, air, and space, and artificial components for the human body. Mechanical engineers are employed throughout the engineering community as individual consultants in small firms providing specialized products or services, as designers and managers in large corporations, and as public officials in government agencies.

Mechanical engineers apply their knowledge to a wealth of systems, products, and processes, including energy generation, utilization and conservation, power and propulsion systems (power plants, engines), and commercial products found in the automotive, aerospace, chemical, or electronics industries.

The B.S. program in Mechanical Engineering at UCLA provides excellent preparation for a career in mechanical engineering and a foundation for advanced graduate studies. Graduate studies in one of the specialized fields of mechanical engineering prepare students for a career at the forefront of technology. The Ph.D. degree provides a strong background for employment by government laboratories, industrial research laboratories, and academia.
Facilities and Services

Teaching and research facilities at HSSEAS are in Boelter Hall, Engineering I, Engineering IV, and Engineering V, located in the southern part of the UCLA campus. Boelter Hall houses classrooms and laboratories for un-dergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoasa.ucla.edu), the SEAS-net computer facility (http://www.seas.ucla.edu/seasnet/), and offices of faculty and administration. The SEL/Engineering and Mathematical Sciences Library is also in Boelter Hall. The Shop Services Center and the Student and Faculty Shop are in the Engineering I building. The California Nano-Systems Institute (CNSI) building hosts additional HSSEAS collaborative research activities.

Library Facilities

University Library System

The UCLA Library, a campuswide network of libraries serving programs of study and research in many fields, is among the top 10 ranked research libraries in the U.S. Total collections number more than 8 million volumes, and nearly 80,000 serial titles are received regularly. Some 15,000 serials and databases are electronically available, and the UCLA Library Catalog is linked to the library’s homepage at http://www.library.ucla.edu.

Science and Engineering Library

The SEL/Engineering and Mathematical Sciences Collection in Boelter Hall houses the engineering, mathematics, statistics, astronomy, chemistry, physics, and atmospheric and oceanic sciences collections, as well as most librarian and staff offices. In addition, the library provides laptop checkout, four group study rooms, a presentation rehearsal studio, and a research commons for collaborative projects. Librarians provide reference assistance from 10 a.m. to 12 noon and 1 to 5 p.m. Monday through Friday in person and by e-mail. Faculty, students, and staff can e-mail questions to SEL librarians at ref@library.ucla.edu.

The SEL/Chemistry collection in the Biomedical Library, located in the Center for Health Sciences, contains complementary journals in chemistry and physics. The SEL/Geology-Geophysics Collection, located at 4697 Geology Building, focuses on earth and space sciences with materials in geochemistry, geology, hydrology, tectonics, water resources, geophysics, and space physics.

The SEL collection contains more than half a million print volumes, subscriptions to nearly 5,000 current serials in print or electronic formats, and over 4 million technical reports. In addition to e-journals, the library provides Web access to article databases covering each discipline and several thousand e-books.

The SEL website, located at http://www.library.ucla.edu/libraries/sel/, highlights other library services including course reserves, laptop lending, interlibrary loan, document delivery and other services, the SEL blog, and others useful engineering Web resources. Librarians are available for consultations and to provide course-related instruction.

Services

Instructional Computer Facility

HSSEAS maintains a network of over 130 enterprise servers that provide a wide array of critical services for School of Engineering students, faculty, and staff. Eight Network Appliance NFS servers supply reliable storage for user’s personal data and e-mail, and offer nearly instant recovery of deleted files through regular snapshots.

More than 100 Unix servers, including 25 virtual machines, provide administrative and instructional support to ensure smooth operation of approximately 700 Linux and Windows workstations. The Unix servers provide back-end services such as DNS, authentication, virtualization, software licensing, web servers, interactive log-in, database, e-mail, class applications, and security monitoring.

Twelve Windows servers make up the backbone for all instructional computing labs and allow students to work remotely with computationally and resource-intensive applications. There are three computer labs and one instructional computer lab with 183 Windows workstations, and an additional computer lab with 16 Linux workstations.

A high-speed network that links the entire infrastructure ensures a latency-free operation for users from UCLA and around the world. It consists of dual fiber uplinks to a Cisco core router that feeds and routes 20 networks, over 150 switches, and 50 Cisco wireless access points. The network serves over 8,000 users across four buildings.

For backup and disaster recovery, large capacity LTO tapes are used to back up servers and selected user workstations regularly, and incremental backups are done to online disk storage. The LTO tapes are sent to off-site storage for disaster recovery.

The servers are protected by two UPS units for short-term power outages, and campus emergency power keeps critical equipment running during extended downtime.

Students and faculty have access to retail Microsoft software through the Microsoft Developer Network Academic Alliance (MSDNAA) program, and MathType software through an HSSEAS download service, at no charge. Faculty and staff have access to Microsoft Office software at no charge through the HSSEAS download service and the Microsoft Consolidated Campus Agreement (MCCA). Autodesk and Dreamspark programs offer additional software at no charge to all UCLA students.

UCLA Academic Technology Services (ATS) operates high-performance computer clusters that offer cluster hosting services to campus researchers in a way that effectively manages the limited high-end data center space on campus. They offer help to researchers who need assistance in numerically intensive computing by speeding up long-running serial or parallel programs or by parallelizing existing serial code. A UCLA Grid Portal and other high-performance computing resources are also available.

The school’s manufacturing engineering program operates a group of workstations dedicated to CAD/CAM instruction, and the Computer Science Department operates a network of SUN, PC, and Macintosh computers. The school is connected via high-speed networks to the Internet, and computing resources at the national supercomputer centers are available.

Shop Services Center

The Shop Services Center is available to faculty, staff, and students for projects.

Continuing Education

UCLA Extension

Department of Engineering and Technology
The Career Center staff also provides consultation services to HSSEAS students. Career services are available at the UCLA Career Center, 501 Westwood Plaza, Strathmore Building, from 9 a.m. to 5 p.m. Monday through Friday, by appointment and for same-day counseling sessions. For more information call (310) 206-1915 or see http://career.ucla.edu.

Arthur Ashe Student Health and Wellness Center

The Arthur Ashe Student Health and Wellness Center is a full-service medical clinic available to all registered UCLA students. Its clinical staff of physicians, nurse practitioners, and nurses is board-certified. It offers primary care, specialty clinics, and physical and occupational therapy. The center has its own pharmacy, optometry, radiology, and laboratory. Visit, core laboratory test, X-ray fees, and preventive immunizations are all pre-paid for students with the University of California Student Health Insurance Plan (UCSHIP). Students with UCHP pay lower co-pays for prescriptions filled at the Ashe Center pharmacy. UCHP students must begin all non-emergency medical care at the Ashe Center. All fees incurred at the Ashe Center are billed directly to students’ BruinBill accounts.

If a student withdraws, is dismissed, has registration fees cancelled, or takes a leave of absence during a term, he or she continues to be eligible for health services for the remainder of the term at full cost. If a student with UCHP withdraws with a less than 100% refund, UCHP continues through the remainder of the term.

The cost of services received outside the Ashe Center is each student’s financial responsibility. Students who waive UCHP need to ensure that they are enrolled in a plan qualified to cover expenses incurred outside of the Ashe Center, and are responsible for knowing the benefits of and local providers for their medical plan.

For emergency care when the Ashe Center is closed, students may call nurse line telephone triage services at (866) 704-9600, or obtain treatment at the UCLA Medical Center Emergency Room or the nearest emergency room on a fee-for-service basis. It is the student’s responsibility to have insurance billed. A student with UCHP must have follow-up visits, after emergencies, in the Ashe Center. If care cannot be provided in the Ashe Center, the Ashe Center clinician will give the student a written referral to a network provider.

The Ashe Center website processes students’ proof of immunity to Hepatitis B prior to enrollment. Information about this requirement is available on the Ashe website; for questions, send e-mail to shshepb@ashe.ucla.edu.

Office hours during the academic year are weekdays 8 a.m. to 6:30 p.m. except Friday, when service begins at 9 a.m. Located at 221 Westwood Plaza (next to John Wooden Center), (310) 825-4073; see http://www.studenthealth.ucla.edu.

Services for Students with Disabilities

The Office for Students with Disabilities (OSD) is the only campus entity authorized to determine a student’s eligibility for disability-related accommodations and services. Academic support services are determined for each regularly enrolled student with documented permanent or temporary disabilities based on specific disability-based requirements. OSD policies and practices comply with all applicable federal and state laws, including Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (ADA) of 1990, and are consistent with University policy.

Services include campus orientation and accessibility, note takers, reader service, sign language interpreters, Learning Disability Program, registration assistance, test-taking facilitation, special parking assistance, real-time captioning, assistive listening devices, on-campus transportation, adaptive equipment, support groups and workshops, tutorial referral, special materials, housing appeals, referral to UCLA’s Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations. There is no fee for any of these services. All contacts and assistance are handled confidentially. Located at A255 Murphy Hall, voice (310) 825-1501, TTY (310) 206-6083; see http://www.osd.ucla.edu.

Dashew Center for International Students and Scholars

The Dashew Center for International Students and Scholars assists international stu-
students with questions about immigration, employment, government regulations, financial aid, academic and administrative procedures, cultural adjustment, and personal matters. The center provides visa assistance for faculty, researchers, and postdoctoral scholars. It also offers programming to meet the needs of the campus multicultural population. Located at 106 Bradley Hall; see http://www.internationalcenter.ucla.edu.

Fees and Financial Support

Fees and Expenses

The 2012-13 annual UCLA student fees shown are current as of publication. See the quarterly Schedule of Classes for breakdown by term or see http://www.registrar.ucla.edu/fees/ for updates.

Students who are not legal residents of California (out-of-state and international students) pay nonresident supplemental tuition. See the UCLA General Catalog appendix or the frequent questions residence section at http://www.registrar.ucla.edu/faq/residence faq.htm for information on how to determine residence for tuition purposes; further inquiries may be directed to the Residence Deputy, 1113 Murphy Hall, UCLA, Los Angeles, CA 90024-1429.

In addition to the fees listed, students should be prepared to pay living expenses for the academic period.

Living Accommodations

Housing in Los Angeles, both on and off campus, is in great demand. Students should make arrangements early.

The Community Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095-1495, (310) 825-4491, http://www.cho.ucla.edu, provides information and current listings for University-owned apartments, cooperatives, private apartments, roommates, rooms in private homes, room and board in exchange for work, and short-term housing. A current BruinCard or a letter of acceptance and valid photo identification card are required for service.

For information on residence halls and suites, contact UCLA Housing Services, 360 De Neve Drive, Box 951381, Los Angeles, CA 90095-1381, (310) 206-7011; see http://www.housing.ucla.edu. Newly admitted students are sent UCLA Housing, which describes costs, locations, and eligibility for both private and UCLA-sponsored housing.

Financial Aid

Undergraduate Students

Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. Applications for each academic year are available in January. The priority application deadline for financial aid for the 2013-14 academic year is March 2, 2013. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA). International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

Information on UCLA financial aid programs is available at the Financial Aid Office, A129J Murphy Hall, (310) 206-0400; see http://www.fao.ucla.edu.

Scholarships

All UCLA undergraduate scholarship awards are made on a competitive basis, with consideration given to academic excellence, achievement, scholastic promise, and financial need. Scholarships are awarded to entering and continuing undergraduates. The term and amount of the award vary; students are expected to maintain academic excellence in their coursework.

Regents Scholarships are awarded to students with an outstanding academic record and a high degree of promise. Regents Scholars receive a yearly honorarium if they have no financial need. If financial need is established, other scholarships and/or grants are awarded to cover that need.

HSSEAS Scholarships are awarded to entering and continuing undergraduate students based on criteria including financial need, academic excellence, community service, extracurricular activities, and research achievement. The school works with alumni, industry, and individual donors to establish scholarships to benefit engineering students. In 2011-12, HSSEAS awarded more than 140 undergraduate scholarship awards totaling more than $310,000. The majority of these scholarships are publicized in the Fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see http://seasoasa.ucla.edu/student-opportunities/scholarships-for-undergraduates.

Grants

Cal Grants A and B are awarded by the California Student Aid Commission to entering and continuing undergraduate students who are U.S. citizens or eligible noncitizens and California residents. Based on financial need and academic achievement, these awards are applied toward tuition and fees.

Federal Pell Grants are federal aid awards designed to provide financial assistance to U.S. citizens or eligible noncitizen undergraduates in exceptional need of funds to attend post-high school educational institu-

| 2012-13 ANNUAL UCLA GRADUATE AND UNDERGRADUATE FEES |
|---------------------------------|-----------------|-----------------|
| Grads | Undergrads | \[
<table>
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<tbody>
<tr>
<td>Student Services Fee</td>
<td>$ 972.00</td>
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<tr>
<td>Tuition</td>
<td>$ 11,220.00</td>
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<tr>
<td>Undergraduate Students Association Fee</td>
<td>$ 122.47</td>
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<tr>
<td>Green Initiative Fee</td>
<td>$ 13.20</td>
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<tr>
<td>PLEDGE Fee</td>
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<tr>
<td>Graduate Students Association Fee</td>
<td>$ 38.25</td>
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<tr>
<td>Graduate Writing Center Fee</td>
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<tr>
<td>Ackerman Student Union Fee</td>
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<tr>
<td>Ackerman/Kerckhoff Seismic Fee</td>
<td>$ 113.00</td>
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<tr>
<td>Wooden Center Fee</td>
<td>$ 51.00</td>
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<tr>
<td>Program, Activities, and Resources Complex Fee</td>
<td>$ 100.00</td>
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<tr>
<td>Student Health Insurance Plan (UCSHIP)</td>
<td>$ 2,242.94</td>
</tr>
<tr>
<td>Nonresident Supplemental Tuition</td>
<td>$ 2,242.94</td>
</tr>
<tr>
<td>Total mandatory fees</td>
<td>$ 14,809.19</td>
</tr>
</tbody>
</table>
Detailed information on other grants for students with demonstrated need is available from the Financial Aid Office.

Federal Family Education Loan Program

Federal loans are available to undergraduate or graduate students who are U.S. citizens or eligible noncitizens and who carry at least a half-time academic workload. Information on loan programs is available from the Financial Aid Office, A125J Murphy Hall, or on the web at http://www.fao.ucla.edu. All loan recipients must complete an exit interview with Student Loan Services and Collections before leaving UCLA for any reason. This interview helps students understand their loan agreement and plan for loan repayment. Failure to complete an exit interview results in a hold being placed on all university services and records. In addition, if the campus-based loans become delinquent following separation from UCLA, all university services and records will be withheld. For further information concerning loan repayment, visit Student Loan Services and Collections, A227 Murphy Hall, (310) 825-9864; see http://www.loans.ucla.edu.

Work-Study Programs

Under Federal Work-Study, the federal government pays a portion of the student’s wage and the employer pays the balance. When possible, work is related to student educational objectives. Hourly pay rates comply with minimum wage laws and vary with the nature of the work, experience, and capabilities. Employment may be on or off campus. To be eligible, undergraduate and graduate students must demonstrate financial need and be a U.S. citizen or eligible noncitizen. Submission of the FAFSA is required.

Students must be enrolled at least half-time (6 units for undergraduates, 4 for graduate students) and not be appointed at more than 50 percent time while employed at UCLA. Students not meeting these requirements are subject to Social Security and Medicare taxation.

Community Service is a component of the Federal Work-Study program. Students who secure a community service position are eligible to petition for an increase in work-study funds up to a total of $5,000 while at the same time reducing their Perkins and/or Stafford loan by the amount of the increase. Most community service positions are located off campus.

Graduate Students

A high percentage of HSSEAS graduate students receive departmental financial support.

Merit-Based Support

Three major types of merit-based support are available in the school:

1. Fellowships from University, private, or corporate funds.
2. Employment as a teaching assistant.
3. Employment as a graduate student researcher.

Fellowships usually provide stipends competitive with those of other major universities, plus tuition and nonresident supplemental tuition (where applicable). These stipends may be supplemented by a teaching assistantship or graduate student researcher appointment. The awards are generally reserved for new students.

Teaching assistantships are awarded to students on the basis of scholarship and promise as teachers. Appointees serve under the supervision of regular faculty members.

Graduate student researcher (GSR) appointments are awarded to students on the basis of scholastic achievement and promise as creative scholars. Appointees perform research under the supervision of a faculty member in research work. Full-time employment in summer and interterm breaks is possible, depending on the availability of research funds from contracts or grants.

Since a graduate student researcher appointment constitutes employment in the service of a particular faculty member who has a grant, students must take the initiative in obtaining desired positions.

GSR appointments are generally awarded after one year of study at UCLA.

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2012-13 competition. Applicants should check the deadline for submitting the UCLA Application for Graduate Admission and the Fellowship Application for Entering Graduate Students with their preferred department.

Need-Based Aid

Unlike the awards above, which are based solely on merit and administered by HSSEAS, the University also provides work-study and low-interest loans based on financial need exclusively.

Need-based awards are administered by the Financial Aid Office in A125J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid (FAFSA).

Continuing graduate students should contact the Financial Aid Office in December 2011 for information on 2012-13 application procedures.

International graduate students are not eligible for need-based University financial aid or for long-term student loans.

School of Engineering Fellowships

Fellowship packages offered by HSSEAS may include fellowship contributions from the following sources:

- AT&T Fellowships. Supports doctoral study in electrical engineering; must be U.S. citizen or permanent resident; optional summer research at AT&T
- Atlantic Richfield Company (ARCO) Fellowship. Department of Chemical and Biomolecular Engineering; supports study in chemical engineering
- William and Mary Beedle Fellowship. Department of Chemical and Biomolecular Engineering; supports study in chemical engineering
- John J. and Clara C. Boelter Fellowship. Supports study in engineering
- Leon and Alyne Camp Fellowship. Department of Mechanical and Aerospace Engineering; supports study in engineering; must be U.S. citizen
- Deutsch Company Fellowship. Supports engineering research on problems that aid “small business” in Southern California
- IBM Doctoral Fellowship. Supports doctoral study in computer science
- Intel Fellowship. Department of Computer Science; supports doctoral study in selected areas of computer science
- Les Knesel Scholarship Fund. Department of Materials Science and Engineering; supports master’s or doctoral students in ceramic engineering
- T.H. Lin Graduate Fellowship. Department of Civil and Environmental Engineering; supports study in the area of structures
- Microsoft Fellowship. Supports doctoral study in computer science
- National Consortium for Graduate Degrees for Minority in Engineering and Science (GEM) Fellowships. Supports study in engineering and science to highly qualified individuals from communi-
ties where human capital is virtually untapped

NCR Fellowship. Department of Computer Science; supports doctoral study in computer science

Martin Rubin Scholarship. Supports two undergraduate or graduate students pursuing a degree in civil engineering with an emphasis in structural engineering

Henry Samueli Fellowship. Department of Electrical Engineering; supports master’s and doctoral students

Henry Samueli Fellowship. Department of Mechanical and Aerospace Engineering; supports master’s and doctoral students

Sun Microsystems Fellowship. Department of Computer Science; supports incoming graduate students in computer science

Texaco Scholarship. Department of Civil and Environmental Engineering; supports research in the area of environmental engineering

Many other companies in the area also make arrangements for their employees to work part-time and to study at UCLA for advanced degrees in engineering or computer science. In addition, the Graduate Division offers other fellowship packages including the Dissertation Year, the Eugene V. Cotab-Acas, and Graduate Opportunity Fellowships.

Special Programs, Activities, and Awards

Center for Excellence in Engineering and Diversity

The HSSEAS Center for Excellence in Engineering and Diversity (CEED) seeks to create a community of collaborative and sustainable partnerships that increase academic opportunities for urban, disadvantaged, and underrepresented students. CEED supports precollege students in science, engineering, mathematics, and technology curricula, and focuses on engineering and computer science at the undergraduate and graduate levels.

Precollege Outreach Programs

Science and Mathematics Achievement and Research Training for Students (SMARTS). A six-week commuter summer program, SMARTS provides a diverse group of up to 50 10th and 11th graders with rigorous inquiry-based engineering, mathematics, and science enrichment. Students receive an introduction to the scientific process and to laboratory-based investigation through the Research Apprentice Program, sponsored by faculty and graduate research mentors in engineering.

Summer Math and Science Honors Academy (SMASH). A rigorous and innovative education program, SMASH increases opportunities for educationally and financially disadvantaged urban school students to excel in the fields of science, technology, engineering, and math (STEM) at the college level for five weeks each summer. SMASH scholars also receive year-round academic support including SAT preparation, college counseling, financial aid workshops, and other activities to ensure continued academic success. Thirty new SMASH scholars are selected each year to attend the residential program each of three summers (after their 9th, 10th, and 11th grade years). Approximately 90 students are expected to be participating in SMASH by summer 2014.

MESA Schools Program (MSP). Through CEED, HSSEAS partners with middle and high school principals to implement MSP services, which focus on outreach and student development in engineering, mathematics, science, and technology. At individual school sites, four mathematics and science teachers serve as MSP advisors and coordinate the activities and instruction for 917 students. Advisers work as a team to deliver services that include SAT preparation. MSP prepares students for regional engineering and science competitions and provides an individual academic planning program, academic excellence workshops, CEED undergraduate mentors, field trips, and exposure to high-tech careers. The MSP goal is to increase the numbers of urban and educationally underserved students who are competitively eligible for UC admission, particularly in engineering and computer science.

Students are provided academic planning, SAT preparation, career exploration, and other services starting at the elementary school level through college. HSSEAS/CEED currently serves 18 schools in the Los Angeles Unified School District and four schools in the Inglewood Unified School District.

Undergraduate Programs

CEED currently supports some 260 underrepresented and educationally disadvantaged engineering students. Components of the undergraduate program include CEED Summer Bridge. A two-week intensive residential summer program, CEED Summer Bridge provides advanced preparation and exposure for Fall Quarter classes in mathematics, chemistry, and computer science.

Freshman Orientation Course. Designed to give CEED freshmen exposure to the engineering profession, “Engineering 87—Engineering Disciplines” also teaches the principles of effective study and team/community-building skills, and research experiences.

Academic Excellence Workshops (AEW). Providing an intensive mathematics/science approach to achieving mastery through collaborative learning and facilitated study groups, workshops meet twice a week for two hours and are facilitated by a Ph.D. student.

Bridge Review for Enhancing Engineering Students (BREES). Sponsored by the National Science Foundation (NSF). A 14-day intensive summer program designed to provide CEED students with the skills and knowledge to gain sufficient mastery, understanding, and problem solving skills in the core engineering courses. Current CEED students and incoming CEED transfer students take part in lectures and collaborative, problem-solving workshops facilitated by UCLA graduate students.

Research Intensive Series in Engineering for Underrepresented Populations (RISE-UP). During the summer of 2005, UCLA CEED began its Research Intensive Series in Engineering for Underrepresented Populations (RISE-UP). The purpose of this program is to keep engineering and computing students, particularly from underrepresented groups, interested in the fun of learning through a process in which faculty participate. The ultimate goal of this program is to encourage these young scholars to go on to graduate school and perhaps the professoriate.

Academic Advising and Counseling. A CEED counselor assists in the selection of course combinations, professors, and course loads and meets regularly with students to assess progress and discuss individual concerns.

Tutoring. Review sessions and tutoring are provided for several upper division engineering courses.

Career Development. Presentations by corporate representatives and field trips to major company locations are offered. Other services include summer and full-time job placement and assistance.
Cluster Systems. Common class sections that team students, Cluster Systems facilitate group study and successful academic excellence workshops.

Student Study Center: A complex with a study area open 24 hours a day, the Student Study Center also houses a computer room and is used for tutoring, presentations, and engineering student organizations.

Frontier Opportunities in Computing for Underrepresented Students (FOCUS). Funded by the National Science Foundation, the FOCUS project is aimed at increasing the number of underrepresented minorities interested in, prepared for, and retained to baccalaureate degree completion in computing disciplines. A collateral goal is to prepare students who possess these skills, knowledge, and resiliency to competitively enter and succeed in either the computing workforce or in graduate studies. FOCUS utilizes bridging programs to build learning communities for incoming freshmen and community college transfer students. During summer and academic year transition programs, FOCUS participants are immersed in computing experiences and computer programming modules to sustain interest, a sense of community, and peer-to-peer support. FOCUS provides academic and non-academic activities such as a mentor program, industry engagement, and opportunities for research internships.

FOCUS conducts counselor and faculty institutes to produce effective and lasting communities of practice and commitment to diversify the computing student population and workforce. It will impact over 400 students over the project life, and will serve as a model to increase retention and performance in the critical gateway computer science courses.

A key component is to establish sustainable partnerships with local two-year colleges. FOCUS targets four community colleges—East Los Angeles, El Camino, Los Angeles Valley, and Santa Monica—to partner with CEED to identify and support students toward participation in computing and a successful transfer into computing at a four-year university. Several other community colleges also partner, to different degrees, with FOCUS. Corporations—including Cisco, Intel, Qualcomm, and Northrop Grumman—support seminars, workshops, and projects as well as summer internships. When the grant period ends in 2013, industry partners’ support will be leveraged to sustain the program.

Scholarships/Financial Aid
The Henry Samueli School of Engineering and Applied Science also participates in the NACME and GEM scholarships. The CEED Industry Advisory Board and support network provide significant contributions to program services and scholarships. Information may be obtained from the CEED director.

Student Organizations
UCLA CEED supports student chapters of three engineering organizations: the American Indian Science and Engineering Society (AISES), the National Society of Black Engineers (NSBE), and the Society of Latino Engineers and Scientists (SOLES), the UCLA chapter of the Society of Hispanic Professional Engineers (SHPE). These organizations are vital elements of the program.

American Indian Science and Engineering Society
AISES encourages American Indians to pursue careers as scientists and engineers while preserving their cultural heritage. The goal of AISES is to promote unity and cooperation and to provide a basis for the advancement of American Indians while providing financial assistance and educational opportunities. AISES devotes most of its energy to its outreach program where members conduct monthly science academies with elementary and precollege students from Indian Reservations. Serving as mentors and role models for younger students enables UCLA AISES students to further develop professionalism and responsibility while maintaining a high level of academics and increasing cultural awareness.

National Society of Black Engineers
Chartered in 1980 to respond to the shortage of blacks in science and engineering fields and to promote academic excellence among black students in these disciplines, NSBE provides academic assistance, tutoring, and study groups while sponsoring ongoing activities such as guest speakers, company tours, and participation in UCLA events such as Career Day and Engineers Week. NSBE also assists students with employment. Through the various activities sponsored by NSBE, students develop leadership and interpersonal skills while enjoying the college experience. UCLA NSBE was recently named national chapter of the year for small chapters by the national organization. See http://sites.google.com/site/uclansbe/.

Society of Latino Engineers and Scientists
Recognized as the national chapter of the year five times over the past ten years years by the Society of Hispanic Professional Engineers (SHPE), SOLES promotes engineering as a viable career option for Latino students. SOLES is committed to the advancement of Latinos in engineering and science through endeavors to stimulate intellectual pursuit through group studying, tutoring, and peer counseling for all members. This spirit is carried into the community with active recruitment of high school students into the field of engineering.

CEED students participate in a professional development workshop.
SOLES also strives to familiarize the UCLA community with the richness and diversity of the Latino culture and the scientific accomplishments of Latinos. SOLES organizes cultural events such as Latinos in Science, Cinco de Mayo, and cosponsors the Women in Science and Engineering (WISE) Day with AISES and NSBE. By participating in campus events such as Career Day and Engineers Week, the organization’s growing membership strives to fulfill the needs of the individual and the community. See http://www.uclasoles.com.

Women in Engineering
Women make up about 21 percent of the HSSEAS undergraduate and 20 percent of the graduate enrollment. Today’s opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a “males only” field. Women engineers are in great demand in all fields of engineering.

Society of Women Engineers
The Society of Women Engineers (SWE), recognizing that women in engineering are still a minority, has established a UCLA student chapter that sponsors field trips and engineering-related speakers (often professional women) to introduce the various options available to women engineers. The UCLA chapter of SWE, in conjunction with other Los Angeles schools, also publishes an annual résumé book to help women students find jobs and presents a career day for women high school students. See http://www.seas.ucla.edu/swe/.

Student and Honorary Societies
Professionally related societies and activities at UCLA provide valuable experience in leadership, service, recreation, and personal satisfaction. The faculty of the school encourages students to participate in such societies and activities where they can learn more about the engineering profession in a more informal setting than the classroom. For more information, see http://www.engineer.ucla.edu/visitor-links/current-students/student-organizations.

<table>
<thead>
<tr>
<th>Society</th>
<th>Description</th>
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<tbody>
<tr>
<td>EGSA</td>
<td>Engineering Graduate Students Association</td>
</tr>
<tr>
<td>ESUC</td>
<td>Engineering Society, University of California. Umbrella organization for all the engineering and technical societies at UCLA</td>
</tr>
<tr>
<td>ACM</td>
<td>Association for Computing Machinery</td>
</tr>
<tr>
<td>AIAA</td>
<td>American Institute of Aeronautics and Astronautics</td>
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<tr>
<td>AICHE</td>
<td>American Institute of Chemical Engineers</td>
</tr>
<tr>
<td>AISES</td>
<td>American Indian Science and Engineering Society</td>
</tr>
<tr>
<td>—</td>
<td>Amateur Radio Club</td>
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<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
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<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
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<tr>
<td>BMES</td>
<td>Biomedical Engineering Society</td>
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<tr>
<td>—</td>
<td>Bruin Amateur Radio Club</td>
</tr>
<tr>
<td>CalGeo</td>
<td>California Geoprofessionals Association</td>
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<tr>
<td>Chi Epsilon</td>
<td>Civil Engineering Honor Society</td>
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<tr>
<td>CSGSC</td>
<td>Computer Science Graduate Student Committee</td>
</tr>
<tr>
<td>Eta Kappa Nu</td>
<td>Electrical engineering honor society</td>
</tr>
<tr>
<td>EWB</td>
<td>Engineers Without Borders</td>
</tr>
<tr>
<td>FEED</td>
<td>Forum for Energy Economics and Development</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
</tr>
<tr>
<td>ISPE</td>
<td>International Society for Pharmaceutical Engineering</td>
</tr>
<tr>
<td>ITE</td>
<td>Institute of Transportation Engineers</td>
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<tr>
<td>LUG</td>
<td>Linux Users Group</td>
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<tr>
<td>MRS</td>
<td>Materials Research Society</td>
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<tr>
<td>NSBE</td>
<td>National Society of Black Engineers</td>
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<tr>
<td>Phi Sigma Rho</td>
<td>Engineering social sorority</td>
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<tr>
<td>PIE</td>
<td>Filipinos in Engineering</td>
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<td>—</td>
<td>Robotics Club</td>
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<tr>
<td>—</td>
<td>Senior Class Campaign</td>
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<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>SOLES</td>
<td>Society of Latino Engineers and Scientists</td>
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<tr>
<td>SWE</td>
<td>Society of Women Engineers</td>
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<tr>
<td>Tau Beta Pi</td>
<td>Engineering honor society</td>
</tr>
<tr>
<td>Triangle</td>
<td>Social fraternity of engineers, architects, and scientists</td>
</tr>
<tr>
<td>Upsilon Pi Epsilon</td>
<td>International honor society for the computing and information disciplines</td>
</tr>
</tbody>
</table>

Student Representation
The student body takes an active part in shaping policies of the school through elected student representatives on the school’s Executive Committee.

Prizes and Awards
Each year, certificates and award monies are presented at the HSSEAS annual commencement ceremony to recognize outstanding students who have contributed to the school.

The Russell R. O’Neill Distinguished Service Award is presented annually to an upper division student in good academic standing who has made outstanding contributions through service to the undergraduate student body, student organizations, the school, and to the advancement of the undergraduate engineering program, through service and participation in extracurricular activities.

The Harry M. Showman Engineering Prize is awarded to a UCLA engineering student or students who most effectively communicate the achievements, research results, or social significance of any aspect of engineering to a student audience, the engineering professions, or the general public.

The Engineering Achievement Award for Student Welfare is given to undergraduate and graduate engineering students who have made outstanding contributions to student welfare through participation in extracurricular activities and who have given outstanding service to the campus community.

Additional awards may be given to those degree candidates who have achieved academic excellence. Criteria may include such items as grade-point average, creativity, research, and community service.

Departmental Scholar Program
The school may nominate exceptionally promising juniors and seniors as Departmental Scholars to pursue bachelor’s and master’s degree programs simultaneously.

Minimum qualifications include the completion of 24 courses (96 quarter units) at UCLA, or the equivalent at a similar institution, the current minimum grade-point average required for honors at graduation, and the requirements in preparation for the major. To obtain both the bachelor’s and master’s degrees, Departmental Scholars fulfill the requirements for each program.
Students may not use any one course to fulfill requirements for both degrees. For details, consult the Office of Academic and Student Affairs in 6426 Boelter Hall well in advance of application dates for admission to graduate standing.

Official Publications
This Announcement of the Henry Samueli School of Engineering and Applied Science contains detailed information about the school, areas of study, degree programs, and course listings. The UCLA General Catalog (http://www.registrar.ucla.edu/catalog), however, is the official and binding document for the guidance of students. UCLA students are responsible for complying with all University rules, regulations, policies, and procedures described in the catalog.

For rules and regulations on graduate study, see http://grad.ucla.edu.

Grading Policy
Instructors should announce their complete grading policy in writing at the beginning of the term, along with the syllabus and other course information, and make that policy available on the course website. Once the policy is announced, it should be applied consistently for the entire term.

Grade Disputes
If students believe that they have been graded unfairly, they should first discuss the issue with the instructor of the course. If the dispute cannot be resolved between the student and the instructor, the student may refer the issue to the Associate Dean for Academic and Student Affairs, 6426 Boelter Hall.

The associate dean may form an ad hoc committee to review the complaint. The ad hoc committee members are recommended by the appropriate department chair and the associate dean. The student receives a copy of the ad hoc committee’s report as well as a copy of the associate dean’s recommendation. The student’s file will contain no reference to the dispute.

The associate dean informs the students of their rights with respect to complaints and appeals at UCLA.

Nondiscrimination
The University of California, in accordance with applicable Federal and State Laws and University Policies, does not discriminate on the basis of race, color, national origin, religion, sex, gender identity, pregnancy (including pregnancy, childbirth, and medical conditions related to pregnancy and childbirth), physical or mental disability, medical condition (cancer-related or genetic characteristics), ancestry, marital status, age, sexual orientation, citizenship, or service in the uniformed services (including membership, application for membership, performance of service, application for service, or obligation for service in the uniformed services). The University also prohibits sexual harassment. This nondiscrimination policy covers admission, access, and treatment in University programs and activities.

Inquiries regarding the University’s student-related nondiscrimination policies may be directed to the UCLA Campus Counsel, 3149 Murphy Hall, Box 951405, Los Angeles, CA 90095-1405, (310) 206-6985.

Inquiries regarding nondiscrimination on the basis of disability covered by the Americans with Disabilities Act (ADA) of 1990 or Section 504 of the Rehabilitation Act of 1973 may be directed to Monroe Gordon, ADA and 504 Compliance, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 825-1514,TTY (310) 206-3349. See http://www.ada.ucla.edu.

Students may complain of any action which they believe discriminates against them on the ground of race, color, national origin, marital status, sex, sexual orientation, disability, or age and may contact the Office of the Dean of Students, 1206 Murphy Hall, and/or refer to Section 111.00 of the University of California Policies Applying to Campus Activities, Organizations, and Students (available in 1206 Murphy Hall or at http://www.ucop.edu/ucophome/coordrew/ucpolicies/aos/toc.html) for further information and procedures.

Harassment
Sexual Harassment
The University of California is committed to creating and maintaining a community where all persons who participate in University programs and activities can work and learn together in an atmosphere free from all forms of harassment, exploitation, or intimidation. Every member of the University community should be aware that the University is strongly opposed to sexual harassment and that such behavior is prohibited both by law and by University policy. The University will respond promptly and effectively to reports of sexual harassment and will take appropriate action to prevent, correct and, if necessary, discipline behavior that violates this policy. See http://www.sexualharassment.ucla.edu.

Definitions
Sexual, racial, and other forms of harassment are defined as follows:

Harassment is defined as conduct that is so severe and/or pervasive, and objectively offensive, and that so substantially impairs a person’s access to University programs or activities that the person is effectively denied equal access to the University’s resources and opportunities on the basis of the individual’s race, color, national or ethnic origin, citizenship, sex, religion, age, sexual orientation, gender identity, pregnancy, marital status, ancestry, service in the uniformed services, physical or mental disability, medical condition, or perceived membership in any of these classifications.

When employed by the University of California, and acting within the course and scope of that employment, students are subject to the University of California Policy on Sexual Harassment. Otherwise, the above paragraph is the applicable standard for harassment by students.

Complaint Resolution
Experience has demonstrated that many complaints of sexual harassment can be effectively resolved through informal intervention. Individuals who experience what they consider to be sexual harassment are advised to confront the alleged offender immediately and firmly.

Additionally, an individual who believes that she or he has been sexually harassed may contact the Sexual Harassment Coordinator in 2241 Murphy Hall or a Sexual Harassment Information Center counselor for help and information regarding sexual harassment complaint resolution or grievance procedures at one of the locations listed below as determined by the complainant’s status at the University at the time of the alleged incident:

1. Campus Human Resources/Employee and Labor Relations, Manager, 200 UCLA Wilshire Center, (310) 794-0860
2. Campus Human Resources/Staff and Faculty Counseling Center, Coordinator, 380 UCLA Wilshire Center, (310) 794-0248
3. Chancellor’s Office, Sexual Harassment Coordinator, 2241 Murphy Hall, (310) 206-3417
4. Counseling and Psychological Services, Director, 221 Wooden Center West, (310) 825-0768
5. David Geffen School of Medicine, Dean’s Office, Special Projects Director, 12-138 Center for the Health Sciences, (310) 794-1958
6. Graduate Division, Office Manager, 1237 Murphy Hall, (310) 206-3269
7. Healthcare Human Resources, Employee Relations Manager, 400 UCLA Wilshire Center, (310) 794-0500
8. Lesbian Gay Bisexual Transgender Campus Resource Center, Director, B36 Student Activities Center, (310) 206-3628
9. Office of the Dean of Students, Assistant Dean of Students, 1206 Murphy Hall, (310) 825-3871
10. Office of Ombuds Services, 105 Strathmore Building, (310) 825-7627; 52-025 Center for the Health Sciences, (310) 206-2427
11. Office of Residential Life, Judicial Affairs Coordinator, 205 Bradley Hall, (310) 825-3401
12. Resnick Neuropsychiatric Hospital, Administration/Human Resources Associate Director, B7-370 Semel Institute, (310) 206-5258
13. School of Dentistry, Assistant Dean, Student Affairs, A0-111 Dentistry, (310) 825-2815
14. Student Legal Services, Director, A239 Murphy Hall, (310) 825-9894
15. UCLA Extension, Human Resources Director, 629 UNEX Building, (310) 825-4287; Student Services Director, 214 UNEX Building, (310) 825-2656

Other Forms of Harassment
The University strives to create an environment that fosters the values of mutual respect and tolerance and is free from discrimination based on race, ethnicity, sex, religion, sexual orientation, disability, age, and other personal characteristics. Certainly, harassment, in its many forms, works against those values and often corrodes a person’s sense of worth and interferes with one’s ability to participate in University programs or activities. While the University is committed to the free exchange of ideas and the full protection of free expression, the University also recognizes that words can be used in such a way that they no longer express an idea, but rather injure and intimidate, thus undermining the ability of individuals to participate in the University community. The University of California Policies Applying to Campus Activities, Organizations, and Students (hereafter referred to as Policies; http://www.ucop.edu/ucophome/coordrev/ucpolicies/acs/ toc.html) presently prohibit a variety of conduct by students which, in certain contexts, may be regarded as harassment or intimidation.

For example, harassing expression which is accompanied by physical abuse, threats of violence, or conduct that threatens the health or safety of any person on University property or in connection with official University functions may subject an offending student to University discipline under the provisions of Section 102.08 of the Policies. Similarly, harassing conduct, including symbolic expression, which also involves conduct resulting in damage to or destruction of any property of the University or property of others while on University premises may subject a student violator to University discipline under the provisions of Section 102.04 of the Policies.

Further, under specific circumstances described in Section 102.11 of the Policies, students may be subject to University discipline for misconduct which may consist solely of expression. Copies of this Policy are available in the Office of the Dean of Students, 1206 Murphy Hall, or in any of the Harassment Information Centers listed below:

1. Counseling and Psychological Services, 221 Wooden Center West, (310) 825-0768, http://www.counseling.ucla.edu
2. Dashew Center for International Students and Scholars, 106 Bradley Hall, (310) 825-1681, http://www.internationalcenter.ucla.edu

Complaint Resolution
One of the necessary measures in our efforts to assure an atmosphere of civility and mutual respect is the establishment of procedures which provide effective informal and formal mechanisms for those who believe that they have been victims of any of the above misconduct.

Many incidents of harassment and intimidation can be effectively resolved through informal means. For example, an individual may wish to confront the alleged offender immediately and firmly. An individual who chooses not to confront the alleged offender and who wishes help, advice, or information is urged to contact any of the Harassment Information Centers listed immediately above.

In addition to providing support for those who believe they have been victims of harassment, Harassment Information Centers offer persons the opportunity to learn about the phenomena of harassment and intimidation; to understand the formal and informal mechanisms by which misunderstandings may be corrected and, when appropriate, student perpetrators may be disciplined; and to consider which of the available options is the most useful for the particular circumstances.

With regard to the Universitywide Student Conduct Harassment Policy, complainants should be aware that not all conduct which is offensive may be regarded as a violation of this Policy and may, in fact, be protected expression. Thus, the application of formal institutional discipline to such protected expression may not be legally permissible. Nevertheless, the University is committed to reviewing any complaint of harassing or intimidating conduct by a student and intervening on behalf of the complainant to the extent possible.
Undergraduate Programs

The Henry Samueli School of Engineering and Applied Science (HSSEAS) offers nine four-year curricula listed below (see the departmental listings for complete descriptions of the programs), in addition to an undergraduate minor in Environmental Engineering.

1. Bachelor of Science in Aerospace Engineering, B.S. A.E.
2. Bachelor of Science in Bioengineering, B.S. B.E.
3. Bachelor of Science in Chemical Engineering, B.S. Ch.E.
4. Bachelor of Science in Civil Engineering, B.S. C.E.
5. Bachelor of Science in Computer Science, B.S. C.S.
6. Bachelor of Science in Computer Science and Engineering, B.S. C.S.&E.
7. Bachelor of Science in Electrical Engineering, B.S. E.E.
8. Bachelor of Science in Materials Engineering, B.S. Mat.E.
9. Bachelor of Science in Mechanical Engineering, B.S. M.E.

The aerospace engineering, chemical engineering, civil engineering, computer science and engineering, electrical engineering, materials engineering, and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The computer science and computer science and engineering curricula are accredited by the Computing Accreditation Commission of ABET, http://www.abet.org.

Admission

Applicants to HSSEAS must satisfy the general admission requirements of the University. See the Office of Admissions and Relations with Schools (UARS) website at http://www.admissions.ucla.edu for details. Applicants must apply directly to HSSEAS by selecting one of the majors within the school or the undeclared engineering option. In the selection process many elements are considered, including grades, test scores, and academic preparation.

Students applying as freshmen or transfers must submit their applications during the November 1 through 30 filing period. In addition, it is essential that official test scores be received no later than the date in January when the December test scores are normally reported.

Applicants must submit scores from an approved core test of mathematics, language arts, and writing. This requirement may be satisfied by taking either (1) the ACT Assessment plus Writing Tests or (2) the SAT Reasoning Test. Applicants to the school are strongly encouraged to also take the following SAT Subject Tests: Mathematics Level 2 and a laboratory science test (Biology E/M, Chemistry, or Physics) that is closely related to the intended major.

Fulfilling the admission requirements, however, does not assure admission to the school. Limits have to be set for the enrollment of new undergraduate students. Thus, not every applicant who meets the minimum requirements can be admitted.

Although applicants may qualify for admission to HSSEAS in freshman standing, many students take their first two years in engineering at a community college and apply to the school at the junior level. Students who begin their college work at a California community college are expected to remain at the community college to complete the lower division requirements in chemistry, computer programming, English composition, mathematics, physics, and the recommended engineering courses before transferring to UCLA.

Admission as a Freshman

University requirements specify a minimum of three years of mathematics, including the topics covered in elementary and advanced algebra and two- and three-dimensional geometry. Additional study in mathematics, concluding with calculus or precalculus in the senior year, is strongly recommended and typical for applicants to HSSEAS.

Freshman applicants must meet the University subject, scholarship, and examination requirements described at http://www.admissions.ucla.edu.

Credit for Advanced Placement Tests

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Tests with scores of 3, 4, or 5. Students with AP Test credit may exceed the 213-unit maximum by the amount of this credit. AP Test credit for freshmen entering Fall Quarter 2012 fulfills HSSEAS requirements as indicated on the AP chart. Students who have completed 36 quarter units after high school graduation at the time of the examination receive no AP Test credit.

Admission as a Transfer Student

Admission as a junior-level transfer student is competitive. The University requires applicants to have completed a minimum of 60 transferable semester units (90 quarter units) and two transferable English courses prior to enrolling at UCLA. In addition, to be considered all applicants to HSSEAS majors must have at least a 3.3 grade-point average in their college work. Many of the majors in the school are impacted. Excellent grades, especially for courses in preparation for the major, are expected.

Completion of the required courses in preparation for the major is critical for admission. Articulation agreements between California community colleges and HSSEAS include college-specific course numbers for these requirements and can be found at http://www.assist.org. Applicants who are lacking two or more of the courses are unlikely to be admitted.

Required preparation for HSSEAS majors:
1. Mathematics, including calculus I and II, calculus III (multivariable), differential equations, and linear algebra
2. Calculus-based physics courses in mechanics, electricity and magnetism, and waves, sound, heat, optics, and modern physics
3. Chemistry, including two terms of general chemistry. The Computer Science and Computer Science and Engineering majors and the electrical engineering and computer engineering options of the Electrical Engineering major require only one term of chemistry
4. Computer programming, including either Java, C, or C++. Applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors must take C++
5. Biology, including one year of biology only for applicants to the Bioengineering major
6. English composition courses, including one course equivalent to UCLAs En-
All units and course equivalents to AP Tests are lower division. If an AP Test has been given UCLA course equivalency (e.g., Economics 2), it may not be repeated at UCLA for units or grade points.

<table>
<thead>
<tr>
<th>AP Test</th>
<th>Score</th>
<th>UCLA Lower Division Units and Course Equivalents</th>
<th>Credit Allowed for University and GE Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td>8 units maximum for all tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>4 units (may petition for Chemistry 20A) plus 4 excess units</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>Computer Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Science (A Test)</td>
<td>3, 4, or 5</td>
<td>2 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>6</td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
<td></td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
<td></td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>French 6 (4 units) plus 4 excess units</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>Level</td>
<td>Units Required</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------</td>
<td>----------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Japanese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Latin</td>
<td></td>
<td>8 units maximum for both tests</td>
<td>No application</td>
</tr>
<tr>
<td>Latin Literature</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 6 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>8 units maximum for both tests</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td>May be applied toward Mathematics 31A</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units</td>
<td>4 units may be applied toward Mathematics 31A</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units</td>
<td>Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td>8 units maximum for all tests</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Mechanics)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Physics 1A)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Electricity and Magnetism)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>
Requirements for B.S. Degrees

The Henry Samueli School of Engineering and Applied Science awards B.S. degrees to students who have satisfactorily completed four-year programs in engineering studies.

Students must meet three types of requirements for the Bachelor of Science degree:

1. University requirements
2. School requirements
3. Department requirements

University Requirements
The University of California has two requirements that undergraduate students must satisfy in order to graduate: (1) Entry-Level Writing or English as a Second Language and (2) American History and Institutions. These requirements are discussed in detail in the Undergraduate Study section of the UCLA General Catalog.

School Requirements
The Henry Samueli School of Engineering and Applied Science has seven requirements that must be satisfied for the award of the degree: unit, scholarship, academic residence, writing, technical breadth, ethics, and general education.

Unit Requirement
The minimum units allowed for HSSEAS students is between 185 and 190, depending on the program. The maximum allowed is 213 units.

After 213 quarter units, enrollment may not normally be continued in the school without special permission from the associate dean. This regulation does not apply to Departmental Scholars.

Scholarship Requirement
In addition to the University requirement of at least a C (2.0) grade-point average in all courses taken at any University of California campus, students must achieve at least a 2.0 grade-point average in all upper division University courses offered in satisfaction of the subject and elective requirements of the curriculum. A 2.0 minimum grade-point average in upper division mathematics, upper division core courses, and the major field is also required for graduation.

Academic Residence Requirement
Of the last 48 units completed for the B.S. degree, 36 must be earned in residence in HSSEAS on this campus. No more than 16 of the 36 units may be completed in Summer Sessions at UCLA.

Writing Requirement
Students must complete the University’s Entry-Level Writing or English as a Second Language (ESL) requirement prior to completing the school writing requirement. Students admitted to the school are required to complete a two-term writing requirement—Writing I and engineering writing. Both courses must be taken for letter grades, and students must receive grades of C or better (C– grades are not acceptable).

Writing I
The Writing I requirement must be satisfied by completing English Composition 3 or 3H with a grade of C or better (C– or a Passed grade is not acceptable) by the end of the second year of enrollment.

The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement Tests in English or a combination of a score of 720 or higher on the SAT Reasoning Test Writing Section and superior performance on the English Composition 3 Proficiency Examination. Students whose native language is not English may satisfy the Writing I requirement by completing English as a Second Language 36 with a grade of C or better (C– or a Passed grade is not acceptable). Admission into the course is determined by completion of English as a Second Language 35 with a passing grade or proficiency demonstrated on the English as a Second Language Placement Examination (ESLPE).

Engineering Writing
The engineering writing requirement is satisfied by selecting one approved engineering writing (EW) course from the HSSEAS writing course list or by selecting one approved Writing II (W) course. The course must be completed with a grade of C or better (C– or a Passed grade is not acceptable). Writing courses are listed in the Schedule of Classes at http://www.registrar.ucla.edu/soc/writing.htm.

Writing courses also approved for general education credit may be applied toward the relevant general education foundational area.

Technical Breadth Requirement
The technical breadth requirement consists of a set of three courses providing sufficient breadth outside the student’s core program. A list of HSSEAS Faculty Executive Committee-approved technical breadth requirement courses is available in the Office of Academic and Student Affairs, and deviations from that list are subject to approval by the associate dean for Academic and Student Affairs. None of the technical breadth requirement courses selected by students
can be used to satisfy other major course requirements.

**Ethics Requirement**

The ethics and professionalism requirement is satisfied by completing one course from Engineering 183EW or 185EW with a grade of C or better (C− or a Passed grade is not acceptable). The course may be applied toward the engineering writing requirement.

**General Education Requirements**

General education (GE) is more than a checklist of required courses. It is a program of study that (1) reveals to students the ways that research scholars in the arts, humanities, social sciences, and natural sciences create and evaluate new knowledge, (2) introduces students to the important ideas and themes of human cultures, (3) fosters appreciation for the many perspectives and the diverse voices that may be heard in a democratic society, and (4) develops the intellectual skills that give students the dexterity they need to function in a rapidly changing world.

This entails the ability to make critical and logical assessments of information, both traditional and digital; deliver reasoned and persuasive arguments; and identify, acquire, and use the knowledge necessary to solve problems.

Students may take one GE course per term on a Passed/Not Passed basis if they are in good academic standing and are enrolled in at least three and one-half courses (14 units) for the term. For details on P/NP grading, see Grading in the Academic Policies section of the UCLA General Catalog or consult the Office of Academic and Student Affairs.

GE courses used to satisfy the engineering writing and/or ethics requirements must be taken for a letter grade.

**Requirements for Students Who Entered Fall Quarter 2005 and Thereafter**

**Foundations of Knowledge**

General education courses are grouped into three foundational areas: Foundations of the Arts and Humanities, Foundations of Society and Culture, and Foundations of Scientific Inquiry.

Five courses (24 units minimum) are required. Engineering writing requirement courses also approved for GE credit may be applied toward the relevant GE foundational areas.

Students must meet with a counselor in the Office of Academic and Student Affairs to determine the applicability of GE Cluster courses toward the engineering writing or GE requirements.

Courses listed in more than one category can fulfill GE requirements in only one of the cross-listed categories.

**Foundations of the Arts and Humanities**

Two 5-unit courses selected from two different subgroups:

- Literary and Cultural Analysis
- Visual and Performance Arts Analysis and Practice

**Foundations of Society and Culture**

Two 5-unit courses, one from each subgroup:

- Historical Analysis
- Social Analysis

**Foundations of Scientific Inquiry**

One course (4 units minimum) from the Life Sciences subgroup or one course from Bioengineering CM145/Chemical Engineering CM145, Chemistry and Biochemistry 153A, or Civil and Environmental Engineering M165/Environmental Health Sciences M165:

Life Sciences

This requirement is automatically satisfied for Bioengineering majors, Chemical Engineering majors, and the biomedical engineering option of the Electrical Engineering major. The requirement may be satisfied for Civil Engineering majors if students select an approved major field elective that is also a course approved under Foundations of Scientific Inquiry.

The aim of courses in this area is to ensure that students gain a fundamental understanding of how scientists formulate and answer questions about the operation of both the physical and biological world. The courses also deal with some of the most important issues, developments, and methodologies in contemporary science, addressing such topics as the origin of the universe, environmental degradation, and the decoding of the human genome.

Through lectures, laboratory experiences, writing, and intensive discussions, students consider the important roles played by the laws of physics and chemistry in society, biology, Earth and environmental sciences, and astrophysics and cosmology.

**Foundations Course Lists**

Creating and maintaining a general education curriculum is a dynamic process; consequently, courses are frequently added to the list. For the most current list of approved courses that satisfy the Foundations of Knowledge GE plan, consult an academic counselor or see [http://www.registrar.ucla.edu/ge/](http://www.registrar.ucla.edu/ge/).

**Requirements for Students Who Entered Prior to Fall Quarter 2005**

For the approved list of courses, see [http://www.seasoasa.ucla.edu/undergraduates/ge-home-page](http://www.seasoasa.ucla.edu/undergraduates/ge-home-page).

**Department Requirements**

Henry Samueli School of Engineering and Applied Science departments generally set two types of requirements that must be satisfied for the award of the degree: (1) Preparation for the Major (lower division courses) and (2) the Major (upper division courses). Preparation for the Major should be completed before beginning upper division work.

**Preparation for the Major**

A major requires completion of a set of courses known as Preparation for the Major. Each department sets its own Preparation for the Major requirements; see the Departments and Programs section of this announcement.
The Major
Students must complete their major with a scholarship average of at least a 2.0 (C) in all courses in order to remain in the major. Each course in the major department must be taken for a letter grade. See the Departments and Programs section of this announcement for details on each major.

Policies and Regulations
Degree requirements are subject to policies and regulations, including the following:

Student Responsibility
Students should take advantage of academic support resources, but they are ultimately responsible for keeping informed of and complying with the rules, regulations, and policies affecting their academic standing.

Study List
Study Lists require approval of the dean of the school or a designated representative. It is the student’s responsibility to present a Study List that reflects satisfactory progress toward the Bachelor of Science degree, according to standards set by the faculty. Study Lists or programs of study that do not comply with these standards may result in enforced withdrawal from the University or other academic action.

Undergraduate students in the school are expected to enroll in at least 12 units each term. Students enrolling in less than 12 units must obtain approval by petition to the dean prior to enrollment in courses. The normal program is 16 units per term. Students may not enroll in more than 21 units per term unless an Excess Unit Petition is approved in advance by the dean.

Minimum Progress
Full-time HSSEAS undergraduate students must complete a minimum of 36 units in three consecutive terms in which they are registered.

Credit Limitations
Advanced Placement Tests
Some portions of Advanced Placement (AP) Test credit are evaluated by corresponding UCLA course number. If students take the equivalent UCLA course, a deduction of UCLA unit credit is made prior to graduation. See the AP chart.

College Level Examination Program
Credit earned through the College Level Examination Program (CLEP) may not be applied toward the bachelor’s degree.

Community College Unit Limit
After students have completed 105 quarter units (regardless of where the units are completed), they do not receive unit credit or subject credit for courses completed at a community college.

Foreign Language
No credit is granted toward the bachelor’s degree for college foreign language courses equivalent to quarter levels one and two if the equivalent of level two of the same language was completed with satisfactory grades in high school.

Minors and Double Majors
HSSEAS students in good academic standing may be permitted a minor or double major. The minor or second major must be outside the school (e.g., Electrical Engineering major and Economics major). HSSEAS students are not permitted to double major with two school majors (e.g., Chemical Engineering and Civil Engineering). Students may file an Undergraduate Request to Double Major or Add Minor form at the Office of Academic and Student Affairs. The school determines final approval of a minor or double major request; review is done on a case by case basis, and filing the request does NOT guarantee approval.

While HSSEAS considers minor or double major requests, specializations are not considered at this time. Students interested in a minor or double major should meet with their counselor in 6426 Boelter Hall.

Advising
It is mandatory for all students entering undergraduate programs to have their course of study approved by an academic counselor. After the first term, curricular and career advising is accomplished on a formal basis. Students are assigned a faculty adviser in their particular specialization in their freshman year.

In addition, all undergraduate students are assigned, by major, to an academic counselor in the Office of Academic and Student Affairs who provides them with advice regarding general requirements for the degrees and University and school regulations and procedures. It is the students’ responsibility to periodically meet with their academic counselor in the Office of Academic and Student Affairs, as well as with their faculty adviser, to discuss curriculum requirements, programs of study, and any other academic matters of concern.

Curricula Planning Procedure
Students normally follow the curriculum in effect when they enter the school. California community college transfer students may also select the curriculum in the catalog in effect at the time they began their community college work in an engineering program, providing attendance has been continuous since that time.

Students admitted to UCLA in Fall Quarter 2012 and thereafter use UCLA’s Degree Audit System which can be accessed via URSA OnLine at http://www.ursa.ucla.edu. Students should contact their academic counselor in 6426 Boelter Hall with any questions.

Students following the 2005-06 through 2011-12 catalog years use the program called Degree Audit Reporting System (DARS) and are able to view the credit they have received and determine which of their degree requirements are left to complete. See http://www.seasoasa.ucla.edu/undergraduates/DARS/.

HSSEAS undergraduate students following a catalog year prior to 2005-06 should schedule an appointment with their academic counselor in 6426 Boelter Hall or by calling (310) 825-9580 to review course credit and degree requirements and for program planning.

The student’s regular faculty adviser is available to assist in planning electives and for discussions regarding career objectives. Students should discuss their elective plan with the adviser and obtain the adviser’s approval.

Students should also see any member or members of the faculty specially qualified in their major for advice in working out a program of major courses.

Students are assigned to advisers by majors and major fields of interest. A specific adviser or an adviser in a particular engineering department may be requested by logging in to CourseWeb (https://courseweb.seas.ucla.edu) and clicking on the “My Advisors” link.

Academic counselors in the Office of Academic and Student Affairs assist students with University procedures and answer questions related to general requirements.
Honors

Dean’s Honors List
Students following the engineering curricula are eligible to be named to the Dean’s Honors List each term. Minimum requirements are a course load of at least 15 units (12 units of letter grade) with a grade-point average equal to or greater than 3.7. Students are not eligible for the Dean’s Honors List if they receive an Incomplete (I) or Not Passed (NP) grade or repeat a course. Only courses applicable to an undergraduate degree are considered toward eligibility for Dean’s Honors.

Latin Honors
Students who have achieved scholastic distinction may be awarded the bachelor’s degree with honors. Students eligible for 2012-13 University honors at graduation must have completed 90 or more units for a letter grade at the University of California and must have attained a cumulative grade-point average at graduation which places them in the top five percent of the school (GPA of 3.869 or better) for summa cum laude, the next five percent (GPA of 3.747 or better) for magna cum laude, and the next 10 percent (GPA of 3.610 or better) for cum laude. The minimum GPAs required are subject to change on an annual basis. Required GPAs in effect in the graduating year determine student eligibility. Based on grades achieved in upper division courses, engineering students must have a 3.869 grade-point average for summa cum laude, a 3.747 for magna cum laude, and a 3.610 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field courses. To be eligible for an award, students should have completed at least 80 upper division units at the University of California.
Graduate Programs

The Henry Samueli School of Engineering and Applied Science (HSSEAS) offers courses leading to the Master of Science and Doctor of Philosophy degrees, to the Master of Science in Engineering online degree, to the Master of Engineering degree, and to the Engineer degree. The school is divided into seven departments that encompass the major engineering disciplines: aerospace engineering, bioengineering, chemical engineering, civil engineering, computer science, electrical engineering, manufacturing engineering, materials science and engineering, and mechanical engineering. Graduate students are not required to limit their studies to a particular department and are encouraged to consider related offerings in several departments.

Also, a one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science.

Graduate degree information is updated annually in Program Requirements for UCLA Graduate Degrees at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm.

Master of Science Degrees

The Henry Samueli School of Engineering and Applied Science offers the M.S. degree in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Manufacturing Engineering, Materials Science and Engineering, and Mechanical Engineering. The thesis plan requires seven formal courses and a thesis, which may be written while the student is enrolled in two individual study courses. The comprehensive examination plan requires nine formal courses and a comprehensive examination. In some fields students may be allowed to use the Ph.D. major field examination to satisfy the M.S. comprehensive examination requirement. Full-time students complete M.S. programs in an average of five terms of study (about a year and a half). To remain in good academic standing, an M.S. student must obtain a 3.0 grade-point average overall and a 3.0 GPA in graduate courses.

Concurrent Degree Program

A concurrent degree program between HSSEAS and the Anderson Graduate School of Management allows students to earn two master's degrees simultaneously: the M.B.A. and the M.S. in Computer Science. Contact the Office of Academic and Student Affairs for details.

Master of Science in Engineering Online Degree

The primary purpose of the Master of Science in Engineering online degree program is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed. For further information, see http://msol.ucla.edu.

Master of Engineering Degree

The Master of Engineering (M.Engr.) degree is granted to graduates of the Engineering Executive Program, a two-year work-study program consisting of graduate-level professional courses in the management of technological enterprises. For details, write to the HSSEAS Office of Academic and Student Affairs, 6426 Boelter Hall, UCLA, Box 951601, Los Angeles, CA 90095-1601, (310) 825-2514.

Engineer Degree

The Engineer (Engr.) degree is similar to the Ph.D. degree in that the program of study is built around a major and two minor fields, and the preliminary written and oral examinations are the same. However, a dissertation is not required. Unlike the Ph.D. degree, the Engineer degree does have a formal course requirement of a minimum of 15 (at least nine graduate) courses beyond the bachelor's degree, with at least six courses in the major field (minimum of four graduate courses) and at least three in each minor field (minimum of two graduate courses in each).

Ph.D. Degrees

The Ph.D. programs prepare students for advanced study and research in the major areas of engineering and computer science. To complete the Ph.D., all candidates must fulfill the minimum requirements of the Graduate Division. Major and minor fields may have additional course and examination requirements. For further information, contact the individual departments. To remain in good academic standing, a Ph.D. student must obtain an overall grade-point average of 3.25.

Established Fields of Study for the Ph.D.

Students may propose other fields of study when the established fields do not meet their educational objectives.

Bioengineering Department

Biomaterials, tissue engineering, and biomechanics
Biomedical instrumentation
Biomedical signal and image processing
Biosystem science and engineering
Medical imaging informatics
Molecular and cellular bioengineering
Neuroengineering

Chemical and Biomolecular Engineering Department

Chemical engineering

Civil and Environmental Engineering Department

Civil engineering materials
Environmental engineering
Geotechnical engineering
Hydrology and water resources engineering
Structures (structural mechanics and earthquake engineering)

Computer Science Department

Artificial intelligence
Computational systems biology
Computer network systems
Computer science theory
Computer system architecture
Graphics and vision
Information and data management
Software systems

Electrical Engineering Department

Circuits and embedded systems
Physical and wave electronics
Signals and systems

Materials Science and Engineering Department

Ceramics and ceramic processing
Electronic and optical materials
Structural materials

Mechanical and Aerospace Engineering Department

Applied mathematics (established minor field only)
Applied plasma physics (minor field only)
Dynamics
Fluid mechanics
Heat and mass transfer
Manufacturing and design
Nanoelectromechanical/microelectromechanical systems (NEMS/MEMS)
Structural and solid mechanics
Systems and control
For more information on specific research areas, contact the individual faculty member in the field that most closely matches the area of interest.

Admission

Applications for admission are invited from graduates of recognized colleges and universities. Selection is based on promise of success in the work proposed, which is judged largely on the previous college record.

Candidates whose engineering background is judged to be deficient may be required to take additional coursework that may not be applied toward the degree. The adviser helps plan a program to remedy any such deficiencies, after students arrive at UCLA.

Entering students normally are expected to have completed the B.S. degree requirements with at least a 3.0 grade-point average in all coursework taken in the junior and senior years.

Students entering the Engineer/Ph.D. program normally are expected to have completed the requirements for the master’s degree with at least a 3.25 grade-point average and to have demonstrated creative ability. Normally the M.S. degree is required for admission to the Ph.D. program. Exceptional students, however, can be admitted to the Ph.D. program without having an M.S. degree.

For information on the proficiency in English requirements for international graduate students, see Graduate Admission in the Graduate Study section of the UCLA General Catalog or refer to http://grad.ucla.edu/gasaa/admissions/INTLREQT.HTM.

To submit a graduate application, see http://www.seasoasa.ucla.edu/admissions/graduate-admissions/. From there connect to the site of the preferred department or program and go to the online graduate application.

Graduate Record Examination

Applicants to the HSSEAS graduate programs are required to take the General Test of the Graduate Record Examination (GRE). Specific information about the GRE may be obtained from the department of interest.

Obtain applications for the GRE by contacting the Educational Testing Service, P.O. Box 6000, Princeton, NJ 08541-6000. See http://www.gre.org.
Bioengineering

UCLA
5121 Engineering V
Box 951600
Los Angeles, CA 90095-1600
(310) 267-4085
fax: (310) 794-5966
e-mail: bioeng@ea.ucla.edu
http://www.bioeng.ucla.edu

Joseph J. DiStefano III, Ph.D.
Gerard C.L. Wong, Ph.D.
Douglas L. Black, Ph.D.
(Microbiology,
Francisco Bezanilla, Ph.D.
Marvin Bergsneider, M.D.,
Professors
Affiliated Faculty
Bill J. Tawil, M.B.A., Ph.D.
Shahrooz Rabizadeh, Ph.D.
Martin O. Culjat, Ph.D.
Debiao Li, Ph.D.
Adjunct Professor
Andrea M. Kasko, Ph.D.
Daniel B. Ennis, Ph.D.
Jacob J. Schmidt, Ph.D.
Aydogan Ozcan, Ph.D.
Daniel T. Kamei, Ph.D.
Pei-Yu Chiou, Ph.D.
Associate Professors
Professor Emeriti
Chih-Ming Ho, Ph.D.
Mark S. Cohen, Ph.D.,
Professors
Benjamin M. Wu, D.D.S., Ph.D.,
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Box 951600

Search our website for Departments and Programs of the School

Scope and Objectives

Faculty members in the Department of Bioengineering believe that the interface between biology and the physical sciences represents an exciting area for science in the twenty-first century. Bioengineering has established itself as an independent field and engineering discipline, resulting in the formation of many new bioengineering departments and the redefinition of established programs. Faculty members have embraced this unique opportunity by developing an innovative curriculum, creating state-of-the-art facilities, and performing cutting-edge research.

Instead of treating bioengineering as an application of traditional engineering, it is taught as an applied science discipline in its own right. The bioengineering program is a structured compilation of unique forward-
looking courses dedicated to producing graduates who are well-grounded in the fundamental sciences and highly proficient in rigorous analytical engineering tools necessary for lifelong success in the wide range of possible bioengineering careers. With these courses and a strong emphasis on research, the program provides a unique engineering educational experience that responds to the growing needs and demands of bioengineering.

Department Mission
The mission of the Bioengineering Department is to perform cutting-edge research that benefits society and to train future leaders in the wide range of possible bioengineering careers by producing graduates who are well-grounded in the fundamental sciences, adept at addressing open-ended problems, and highly proficient in rigorous analytical engineering tools necessary for lifelong success.

Undergraduate Program Objectives
The goal of the bioengineering curriculum is to train future leaders by providing students with the fundamental scientific knowledge and engineering tools necessary for graduate study in engineering or scientific disciplines, continued education in health professional schools, or employment in industry. There are five main objectives: graduates (1) participate in graduate, professional, and continuing education activities that demonstrate an appreciation for lifelong learning, (2) demonstrate professional, ethical, societal, environmental, and economic responsibility (e.g., by active membership in professional organizations), (3) demonstrate the ability to identify, analyze, and solve complex, open-ended problems by creating and implementing appropriate designs, (4) work effectively in teams consisting of people of diverse disciplines and cultures, and (5) be effective written and oral communicators in their professions or graduate/professional schools.

Undergraduate Study
The Bioengineering major is a designated capstone major. Utilizing knowledge from previous courses and new techniques learned from the capstone courses, undergraduate students work in teams to apply advanced knowledge of mathematics, science, and engineering principles to address problems at the interface of biology and engineering and to develop innovative bioengineering solutions to meet specific sets of design criteria. Coursework entails construction of student designs, project updates, presentation of projects in written and oral format, and team competition.

Bioengineering B.S. Capstone Major

Preparation for the Major
Required: Bioengineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B, 30BL; Computer Science 31; Life Sciences 2 (satisfies HSSEAS GE life sciences requirement), 3, 4, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4A, 4B, 4L.

The Major
Required: Bioengineering 100, C106, 110, 120, 165EW (or Engineering 183EW or 185EW), 167L, 176, 180, Chemistry and Biochemistry 153A, Electrical Engineering 100; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Bioengineering 177A, 177B); and three major field elective courses (12 units) from Bioengineering C101, CM102, CM103, C104, C105, C131, CM140, CM145, C147, CM150, CM150L, C170, C171, CM178, C179, 180L, 181, 181L, C183, C185, CM186, CM187, 199 (8 units maximum). The three technical breadth and three major field elective courses may also be selected from one of the following tracks. Bioengineering majors cannot take bioengineering technical breadth courses to fulfill the technical breadth requirement.

Biomaterials and Regenerative Medicine: Bioengineering C104, C105, CM140, C147, C183, C185, 199 (8 units maximum), Chemistry and Biochemistry C140, C181, Materials Science and Engineering 104, 110, 111, 120, 130, 132, 140, 143A, 150, 151, 160, 161, Molecular, Cell, and Developmental Biology 168. The above materials science and engineering courses may be used to satisfy the technical breadth requirement.

Biomedical Devices: Bioengineering C131, C172, 199 (8 units maximum), Electrical Engineering 102, CM150 (or Mechanical and Aerospace Engineering CM180), CM150L (or Mechanical and Aerospace Engineering CM180L), Mechanical and Aerospace Engineering C187L. The electrical engineering or mechanical and aerospace engineering courses listed above may be used to satisfy the technical breadth requirement.

For Bioengineering 199 to fulfill a track requirement, the research project must fit within the scope of the track field, and the research report must be approved by the supervisor and vice chair.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.
Graduate Study

For information on graduate admission, see Graduate Programs, page 23.

The following introductory information is based on the 2012-13 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

The Bioengineering Department offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Bioengineering.

Bioengineering M.S.

Students are expected to complete 42 units, which in most cases include either Bioengineering C201, CM202, and CM203, or C204, C205, and C206, and two courses from their area of study. The M.S. degree is offered under both the thesis plan and comprehensive examination plan. Under the thesis plan, 8 units of thesis work may be applied toward the unit requirements for the degree. The comprehensive examination plan consists entirely of coursework (12 courses) and a comprehensive examination. Eight of the 12 courses must be graduate (200-level) courses, and students must maintain a grade-point average of B or better in both upper division and graduate courses. Three Bioengineering 299 courses (6 units total) are also required.

Bioengineering Ph.D.

The Ph.D. program prepares students for advanced study and research in bioengineering. The Ph.D. preliminary examination typically consists of both written and oral parts. To receive a pass on the examination, students must receive a pass on both parts. An oral qualifying/advancement to candidacy examination, coursework for two minor fields of study, and defense of the dissertation are also required. The major field consists of six courses, and defense of the dissertation is also required. The minor field consists of three 4-unit courses, of which two must be graduate (200-level) courses. One minor must be in another field of biomedical engineering. Students must maintain a grade-point average of 3.25 or better in all courses.

Fields of Study

Biomaterials, Tissue Engineering, and Biomechanics

Three subfields—biomechanics, biomaterials, and tissue engineering—encompass this broad field. The properties of bone, muscles, and tissues, the replacement of natural materials with artificial compatible and functional materials such as polymer composites, ceramics, and metals, and the complex interactions between implants and the body are studied.

Course Requirements

Core Courses (Required). Bioengineering 176, C201, C204, C205, C206, and two courses from CM240, CM278, C283, C285, Molecular, Cell, and Developmental Biology 100, 104AL, 138, M140, 165A, 168.

Electives. Students are expected to fulfill the remaining course requirements from courses in this group listed on the Bioengineering website at http://www.bioeng.ucla.edu.

Biomedical Instrumentation

The biomedical instrumentation field trains bioengineers in the applications and development of instrumentation used in medicine and biotechnology. Examples include the use of lasers in surgery and diagnostics, sensors for detection and monitoring of disease, and microelectromechanical systems (MEMS) devices for controlled drug delivery, surgery, or genetics. The principles underlying each instrument and the specific needs in medical applications are emphasized.

Course Requirements

Core Courses (Required). Bioengineering C201, CM202, CM203, M214A, Electrical Engineering 113, 211A.


Remedial Courses. Electrical Engineering 102, Program in Computing 10A, 10B.

Biosystem Science and Engineering

Graduate study in biosystem science and engineering is intended for science or engineering students interested in systems biology biosystems or biomedical systems, with an emphasis on systems and integration. This encompasses the systems engineering/cybernetics-based integrative properties or behavior of living systems, including their regulation, control, integration, and intercommunication mechanisms, and their associated measurement, visualization, and mathematical and computer modeling.

The program provides directed interdisciplinary biosystem studies to establish a foundation in system and information science, mathematical modeling, measurement and integrative biosystem science, as well as related specialized life sciences domain studies. It fosters careers in research and teaching in systems biology engineering, medicine, and/or the biomedical sciences, or research and development in the biomedical or pharmaceutical industry. At the system and integration level, biosystem science and engineering is quite broadly

imaging, computed tomography (CT), and magnetic resonance (MR), positron emission tomography (PET) and SPECT, optical microscopy, and combinations such as PET/MR, (2) signal processing research on hearing to voice recognition to wireless sensors, and (3) bioinformatics research ranging from image segmentation for content-based retrieval from databases to correlating clinical findings with genomic markers. Graduates of the program integrate advanced digital processing and artificial intelligence technologies with healthcare activities and biomedical research. They are prepared for careers involving innovation in the fields of signal processing, medical imaging, and medical-related informatics in either industry or academia.

Course Requirements

Students selecting biomedical signal and image processing as a minor field must take three courses, of which at least two must be graduate (200-level) courses.

Core Courses (Required). Bioengineering C201, CM202, CM203, M214A, Electrical Engineering 113, 211A.


Remedial Courses. Electrical Engineering 102, Program in Computing 10A, 10B.
applicable to a large spectrum of biomedical problems.

Typical research areas include basic and clinical problems in biomedical systems, systems biology, all types of biocontrol systems, imaging systems, pharmaceutical systems, biotechnology systems, bioinformatics, genomics, neuroscience, and remote sensing systems for the life sciences.

Faculty research areas include computational biology, computational biochemistry, and metabolism; computational cardiology and neuroendocrinology; biomodeling of diseases, cellular processes, metabolic control systems, and gene networks; modeling in genomics, pharmacokinetics, and pharmacodynamics; vision, robotics, speech processing, neuroscience, artificial and real neural network modeling, normative expert systems, wireless remote sensing systems, telemedicine, visualization, and virtual clinical environments.

**Course Requirements**

Biosystem science and engineering can serve as a minor field for other Ph.D. majors if students complete the following courses with a grade-point average of B+: Bioengineering CM286, M296A, and one additional graduate-level elective from the additional foundations or electives list.

**Core Courses (Required).** Bioengineering C201, CM202, CM203, CM286, CM287, and either M296A or Biomathematics 220.


**Medical Imaging Informatics**

The objective of the medical imaging informatics field is to train students in imaging-based medical informatics. Specifically, the program’s aims are to enable (1) students from engineering backgrounds to become familiar with aspects of clinical and medical environments, such that they are able to appropriately apply their skills and knowledge in these domains, (2) students from medical backgrounds to learn sufficient expertise in current information and engineering technologies to address specific problems within clinical environments, (3) all students to be experts within the field of imaging-based medical informatics, becoming experienced in dealing with diverse biomedical data (imaging and text), and (4) all students to learn to work in a multidisciplinary group of researchers and individuals, enabling new developments within the field.

The underlying goal is to foster a community for students and faculty members from multiple disciplines (represented by individuals from the Schools of Engineering, Education and Information Studies, Medicine, and Public Health) to participate in the growing area of medical imaging informatics.

**Course Requirements**


**Molecular and Cellular Bioengineering**

The field of molecular and cellular bioengineering encompasses the engineering of enzymes, cellular metabolism, biological signal transduction, and cell-cell interactions. Research emphasizes the fundamental basis for diagnosis, disease treatment, and redesign of cellular functions at the molecular level. This field interacts closely with the fields of bioinstrumentation (MEMS), tissue engineering, and neuroengineering. Graduates of the program are targeted principally for employment in academia, in government research laboratories, and in the biotechnology, pharmaceutical, and biomedical industries.

**Course Requirements**

**Core Courses (Required).** Bioengineering C201, C204, C206, C209, and two courses from 100, M184, M215, M225, CM245, CM283, CM286, CM287, Biomathematics 220, M270, M271, Computer Science 170A, Mathematics 146, 151A, Physiological Science 134, Statistics 200B.

**Electives.** Students are expected to fulfill the remaining course requirements from courses in this group listed on the Bioengineering website at http://www.bioeng.ucla.edu.

**Neuroengineering**

The neuroengineering field is a joint endeavor between the Neuroscience Interdepartmental Ph.D. Program in the Geffen School of Medicine and the Bioengineering Department at HSS/EP.

The objectives of the neuroengineering field are to enable (1) students with a background in engineering to develop and execute projects that address problems that have a neuroscientific base, (2) students with a background in biological sciences to develop and execute projects that make use of state-of-the-art technology, and (3) trainees to develop the capacity for the multidisciplinary teamwork that is necessary for new scientific insights and dramatic technological progress. Courses and research projects are cosponsored by faculty members in both HSS/EP and the Brain Research Institute (BRI).

**Requisites for Admission.** Students entering the neuroengineering program have graduated with undergraduate degrees in engineering, physics, chemistry, or one of the life sciences (for example, biology, microbiology, immunology, and molecular genetics, molecular cell, and developmental biology, neuroscience, physiology, or psychology). Engineering students must have taken at least one undergraduate course in biology, one course in chemistry, and a year of physics. Students from nonengineering backgrounds are required to have taken courses in undergraduate calculus, differential equations, and linear algebra, in addition to at least a year of undergraduate courses in each of the following: organic chemistry and biochemistry, physics, and biology. Students lacking one or more requisite courses, if they are otherwise admissible, are provided an opportunity for appropriate coursework or tutorial during the summer before they enter the neuroengineering program.

**Written Preliminary Examination.** The Ph.D. preliminary examination typically consists of three written parts—two in neuroscience and one in neuroengineering. To receive a pass on the examination, students must receive a pass on all parts. Students who fail the examination may repeat it only once, subject to approval of the faculty examination committee.

Students who are in a field other than neuroengineering and who select neuroengineering as a minor must take Bioengineering M260, M263, and Neuroscience 205.

**Core Courses (Required).** Bioengineering M260, Neuroscience M202, 207, and either Bioengineering M263 or Neuroscience 205.

**Electives.** During the first and second years, students take at least three courses selected from a menu of new and existing courses.
Faculty Areas of Thesis Guidance

Professors

Denise Aberle, M.D. (Kansas, 1979)

Medical imaging informatics: imaging-based clinical trials, medical data visualization
Mark S. Cohen, Ph.D. (Rockefeller, 1985)

Rapid methods of MR imaging, fusion of electrophysiology and fMRI, advanced approaches to MRI data analysis, ultra-low field MRI using SQUID detection, low energy focused ultrasound for neurostimulation
Linda L. Demer, M.D., Ph.D. (Johns Hopkins, 1983)

Vascular biology, biomaterialization, vascular calcification, mesenchymal stem cells
Timothy J. Deming, Ph.D. (UC Berkeley, 1993)

Polymer synthesis, polymer processing, supermolecular materials, organometallic catalysis, biomimetic materials, polypeptides
James Dunn, M.D., Ph.D. (Harvard, MIT, 1992)

Tissue engineering, stem cell therapy, regenerative medicine
Warren S. Grulke, M.D., FACS (Columbia, 1980)

Excimer laser, minimally invasive surgery, biological spectroscopy
Chin-Ming Ho, Ph.D. (Johns Hopkins, 1974)

Molecular mechanics, nanofluidics, and bio-nano research
Bahram Jalali, Ph.D. (California, 1989)

RF photonics, fiber-optic integrated circuits, integrated optics, microwave photonics
Wentai Liu, Ph.D. (Michigan, Ann Arbor, 1983)

Neural engineering
Gerald C.L. Wong, Ph.D. (UC Berkeley, 1994)

Antimicrobials and antibiotic-resistant pathogens, bacterial communities, cystic fibrosis, apoptosis proteins and cancer therapeutics, disinfection processes, purification, self-assembly in biology and biotechnology, physical chemistry of solvation, soft condensed matter physics, biophysics

Biomaterials, cell-material interactions, materials processing, tissue engineering, prosthetic and regenerative dentistry

Professor Emeriti


Stem cell identification, regenerative medicine, systems biology

Associate Professors

Pei-Yu Chiou, Ph.D. (UC Berkeley, 2005)

Optofluidics systems
Dino Di Carlo, Ph.D. (UC Berkeley, 2006)

Microfluidics, biomechanical microdevices, cellular diagnostics, cell analysis and engineering
Daniel T. Kamei, Ph.D. (MIT, 2001)

Molecular cell bioengineering, rational design of molecular therapeutics, systems-level analyses of cellular processes, drug delivery, diagnostics
Aydogan Ozcan, Ph.D. (Stanford, 2005)

Photonics, nano- and bio-technology
Jacob J. Schmidt, Ph.D. (Minnesota, 1999)

Bioengineering and biophysics at micro and nanoscales, membrane protein engineering, biological-inorganic hybrid devices

Assistant Professors

Daniel B. Ennis, Ph.D. (Johns Hopkins, 2004)

MRI, cardiovascular pathophysiology, image processing, continuum mechanics, tensor analysis, soft tissues biomechanics
Andrea M. Kasco, Ph.D. (U. Akron, 2004)

Polymer synthesis, biomaterials, tissue engineering, cell-material interactions

Adjunct Professor

Debiao Li, Ph.D. (U. Virginia, 1992)

Development and clinical application of fast MR imaging techniques for the evaluation of the cardiovascular system

Adjunct Assistant Professors

Martin O. Culliat, Ph.D. (UCLA, 2005)

Devices for image-guided surgical and interventional techniques

Kayvan Niazi, Ph.D. (UCLA, 2000)

Molecular and cellular bioengineering, immunotherapeutics
Shahrooz Rajaee, Ph.D. (UCLA, 1999)

Molecular and cellular bioengineering, drug discovery in cancer and neurodegeneration

Skin tissue engineering, bone tissue engineering, vascular tissue engineering, wound healing

Affiliated Faculty

For areas of thesis guidance, see http://www.bioeng.ucla.edu/people/faculty/affiliate-faculty-1.

Lower Division Courses

10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields of bioengineering, including biosensors, bioinstrumentation, and biosignal processing, biomechanics, biomaterials, tissue engineering, biotechnology, biological imaging, biomedical optics and lasers, bioengineering, and biomolecular machines. Letter grading.

Mr. Deming (F)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A, Physics 1B. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamic analysis of biological systems. Material, energy, charge, and force balances. Introduction to neural system analysis. Letter grading.

Mr. Kamei (W)


Mr. Kamei (F)

CM102. Basic Human Biology for Bioengineers I. (4) Formerly numbered Biomedical Engineering CM102.) (Same as Physiological Science CM102.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to biological science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) to system basis, with particular emphasis on molecular basis. Models/simulations of functional aspect of biological system included. Actual demonstration of biomolecular instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM202. Letter grading.

Mr. Grundfest (F)

C104. Physical Chemistry of Biomacromolecules. (4) (Formerly numbered M104.) Lecture, three hours; discussion, one hour; outside study, seven hours. (Formerly numbered Biomedical Engineering CM107.) Polymer Chemistry and Bioconjugates for some sample applications. Concurrency scheduled with course CM203. Letter grading. Ms. Kasko (F).

C105. Biopolymer Chemistry and Bioconjugates. (4) (Formerly numbered M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 120, Life Sciences 2, 2L, Mathematics 33B, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of ion-toting ionic conductance through artificial or protein nanopores. Physics of pore conductance. Applica- tions to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrically controllable microporous membranes. Fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C205. Letter grading. Mr. Deming (W).

C106. Topics in Biophysics, Channels, and Membranes. (4) (Formerly numbered M106.) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4, 23L, Mathematics 33B, Physics 1C, 4AL, 4BL. Introduction to single-molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrically controllable microporous membranes. Fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C205. Letter grading. Mr. Deming (W).

C110. Polymer Chemistry for Bioengineers. (4) (Formerly numbered M107.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 140 or 140S. Fundamental concepts of polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control polymer structure and properties, and chain-end functionality, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different polymerization tech- niques. Concepts of step-growth, chain-growth, ring-opening, polymerization, chain transfer, and ef- fects of synthesis route on polymer properties. Lectures include both theory and practical issues demon- strated through examples. Concurrently scheduled with course C207. Letter grading. Mr. Deming (W).

C114. Introduction to Biomechanics. (4) (Formerly numbered Biomedical Engineering CM140.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 120, Life Sciences 2, 2L, Mathematics 33B, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of ion-toting ionic conductance through artificial or protein nanopores. Physics of pore conductance. Applica- tions to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrically controllable microporous membranes. Fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C231. Letter grading. Mr. Schmidt (Sp).

CM145. Molecular Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, eight hours. (Formerly numbered Biomedical Engineering CM145.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Mechanical and Aerospace Engineering 101, 102, 156A. Introduction to mechanical functions of human body: skeletal adaptations to optimize load transfer, mobili- ty, and function. Dynamics and kinematics. Fluid mechanics of load transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading. Mr. Gupta (W).

C147. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) (Formerly numbered Biomedical Engineering CM147.) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: courses CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artifi- cial tissues into clinically viable products. Topics include biomaterials selection, cell source, development processes, FDA approval processes, and physical and chemical testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial per- spectives of tissue engineering products. Manufacturing constraints, clinical efficacy, and regulatory challenges in design and development of tissue-engine- neering devices. Concurrently scheduled with course C170L. Letter grading. Mr. Wu (F).

CM150. Introduction to Micromachining and Micro- electromechanical Systems (MEMS). (4) (Formerly numbered Biomedical Engineering CM150.) (Same as Electrical Engineering CM150) Lecture, one hour; laboratory, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL. Introduction to micromachining and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS de- vice. Concurrently scheduled with course CM250A. Letter grading. Mr. Judy (F).

CM150L. Introduction to Micromachining and Micro- electromechanical Systems (MEMS) Laboratory. (2) (Formerly numbered Biomedical Engineering CM150L.) (Same as Electrical Engineering CM150L) Laboratory, one hour; outside study, one hour. Enforced requisites: courses CM150, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining technolo- gies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design high performance fabri- cating MEMS device. Concurrently scheduled with course CM250L. Letter grading. Mr. Judy (F).

165EW. Bioengineering Ethics. (4) (Formerly numbered M165.) Lecture, four hours; discussion, three hours; outside study, five hours. All professions have ethical rules that derive from moral theory. Bioethics is well-established discipline that addresses ethical problems about life, such as when does fertilized eggs become human? Should ending of life ever be assist- ed? At what cost should it be maintained? Unlike phys- cians, bioengineers do not make these decisions in practice. Bioengineering ethics addresses specific problems about producing devices from molecules to bridges, such as when do concerns about risk out- weigh concerns about cost? When are weapons too dangerous to design? At what cost of a benefit of committing to building devices outweigh need to wait for more scientific confirmation of their effectiveness? Bioengineers must be aware of consequences of apply- ing such devices to all living systems. Emphasis on research and writing within engineering environment. Satisfies engineering writing requirement. Letter grading. Mr. Wu (W).

167L. Bioengineering Laboratory. (4) (Formerly numbered M167L.) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: Chemistry 20L. Laboratory experiments in fluores- cence microscopy, bioconjugation, soft lithography, and cell culture culminate in microfabricated surface for cell growth. Introduction to techniques used in laboratories and their underlying physical or chemical properties. Case studies connect laboratory techniques to current biomedical engineering re- search and reinforce experimental design skills. Letter grading. Mr. Di Carlo, Mr. Wong (Sp).

C170. Energy-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C170.) Lecture, three hours; discussion, five hours; outside study, five hours. Enforced requisites: courses CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artifi- cial tissues into clinically viable products. Topics include biomaterials selection, cell source, development processes, FDA approval processes, and physical and chemical testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial per- spectives of tissue engineering products. Manufacturing constraints, clinical efficacy, and regulatory challenges in design and development of tissue-engine- neering devices. Concurrently scheduled with course C170L. Letter grading. Mr. Di Carlo, Mr. Wong (Sp).
underlying various types of energy-tissue interactions. Concurrently scheduled with course C270. Letter grading.

C170L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) (Formerly numbered Biomedical Engineering C170L.) Laboratory, four hours; outside study, two hours. Corequisites: course C170. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissue/tissue mimics and light-tissue interaction, determination of optical properties of different tissues, techniques of temperature distribution measurements. Concurrently scheduled with course C270L. Letter grading.

C171. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) (Formerly numbered Biomedical Engineering C171.) Lecture, four hours; outside study, eight hours. Requisite: course C170. Designed for photonics and optoelectronics engineering majors. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biologic media. Concurrently scheduled with course C271. Letter grading. Mr. Grundfest (W)

C172. Design of Minimally Invasive Surgical Tools. (4) (Formerly numbered M172.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, 23L, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biopsy devices, laparoscopic tools, cardiovascular and interventional radiologic services, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of design concept and consideration of development of new and novel devices. Concurrently scheduled with course C272. Letter grading. Mr. Grundfest (F)

176. Principles of Biocompatibility. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 100, Electrical Engineering 1 or Physics 1C, Mathematics 33B. Biocompatibility at systemic, tissue, cellular, and molecular levels. Biomechanical aspects of strain/constitutive equations, cellular and molecular response to mechanical signals, biochemical and cellular compatibility, immune response. Letter grading. Mr. Wu (Sp)

177A. Bioengineering Capstone Design I. (4) (Formerly numbered 182B.) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: courses 167L, 176, Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including topics such as need finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to address current problems in medicine and biology. Sourcing and ordering of materials and supplies relevant to student projects. Exploration of different experimental and computational methods. Scientific presentation of progress. Letter grading. Mr. Di Carlo, Mr. Wong (W)

177B. Bioengineering Capstone Design II. (4) (Formerly numbered 182C.) Lecture, two hours; laboratory, four hours; outside study, four hours. Enforced requisites: course 177A. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including meetings with scientific/clinical advisors and guest speakers from scientific/industry. Working in teams, students develop innovative solutions to address current problems in medicine and biology. Students conduct directed experiments, present experimental modeling, oral presentations, write reports, and participate in bioengineering design competition. Letter grading. Mr. Di Carlo, Mr. Wong (W)

CM178. Introduction to Biomaterials. (4) (Formerly numbered Biomedical Engineering CM180.) Same as Materials Science and Engineering CM180. Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM278. Letter grading. Mr. Wu (W)

C179. Biomaterials-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C181.) Lecture, three hours; outside study, nine hours. Requisites: course CM178. In-depth exploration of host cellular response to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adherence, and role of mechanical forces. Concurrently scheduled with course C279. Letter grading. Mr. Wu (Sp)

180. System Integration in Biology, Engineering, and Medicine I. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: courses 100, 110, 120, Life Sciences 3, Physics 4BL. Corequisite: course 180L. Part I of two-part series. Molecular basis of normal physiology and pathophysiology of selected organ systems; design principles of cardiovascular and pulmonary systems. Fundamental engineering principles of selected medical therapeutic devices. Letter grading.

Mr. Dunn, Mr. Wu (W)

180L. System Integration in Biology, Engineering, and Medicine I Laboratory. (3) Lecture, one hour; laboratory, four hours; clinical visits, three hours; outside study, one hour. Corequisite: course 180L. Hands-on experimentation and clinical applications of selected medical therapeutic devices associated with cardiovascular and pulmonary disorders. Letter grading.

Mr. Dunn, Mr. Wu (Sp)

181. System Integration in Biology, Engineering, and Medicine II. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 180L. Corequisite: course 181L. Part II of two-part series. Molecular basis of normal physiology and pathophysiology of selected organ systems; engineering design principles of digestive and urinary systems. Fundamental engineering principles of selected medical therapeutic devices. Letter grading.

Mr. Dunn, Mr. Wu (W)

181L. System Integration in Biology, Engineering, and Medicine II Laboratory. (3) Lecture, one hour; laboratory, four hours; clinical visits, three hours; outside study, one hour. Corequisite: course 181L. Hands-on experimentation and clinical applications of molecular basis of normal physiology and pathophysiology of selected organ systems; engineering design principles of digestive and urinary systems. Letter grading.

Mr. Dunn, Mr. Wu (W)

C183. Targeted Drug Delivery and Controlled Drug Release. (4) (Formerly numbered M183.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapeutics require comprehensive understanding of modern biology, physiology, biomaterials, and engineering. Targeted delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacokinetics and pharmacodynamics. CME 394 is recommended. Letter grading.

Mr. Dunn, Mr. Wu (W)

M184. Introduction to Computational and Systems Biology. (3) (Formerly numbered Biomedical Engineering M184.) Same as Computational and Systems Biology M184 and Computer Science M184.) Lecture, two hours; outside study, four hours. Requisites: Computer Science 31 or Program in Computing 10A, Mathematics 31A, 31B. Survey course designed to introduce computational and systems modeling and computation in biology and medicine, providing motivation, flavor, cultural context, and specialty of faculty member teaching. Introduces basic a biobiosciences and aiming for more informed basis for focused studies by students with computational and systems biology interests. Presentations by individual UCLA researchers discussing their active computational and systems biology research. Offered P/N grading.

Mr. DiStefano (W)

C185. Introduction to Tissue Engineering. (4) (Formerly numbered Biomedical Engineering C185.) Lecture, four hours; discussion, two hours; outside study, eight hours. Requisites: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences to engineering cellular/molecular tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffold, and molecular signals. Concurrently scheduled with course C285. Letter grading. Mr. Wu (Sp)

CM186. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered Biomedical Engineering CM186.) (Same as Computational and Systems Biology M186 and Computer Science C186.) Lecture, two hours; laboratory, four hours; outside study, eight hours. Corequisite: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/medical processes and systems at multiple levels of organization. Control system, multicompartamental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and biochemical models and their application to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organ system levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286. Letter grading.

Mr. DiStefano (F)

CM187. Thesis Research and Research Community. (2 to 4) (Formerly numbered Biomedical Engineering CM187.) (Same as Computational and Systems Biology M187 and Computer Science CM187.) Lecture, one hour; discussion, one hour; laboratory, one hour; outside study, eight hours. Requisite: course CM186. Closely directed, interactive, and real research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Criteria of oral presentations and written progress report on how to approach and search rate for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading.

Mr. DiStefano (Sp)

188. Special Courses in Bioengineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics in bioengineering for undergraduate students taught on experimental or temporary basis, such as temporary resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Bioengineering. (4) Seminar, three hours. Limited to bioengineering undergraduate students who are part of research group. Study and analysis of current topics in bioengineering. Discussion of current research literature in research specialty of faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit. Letter grading.
Graduate Courses

C201. Engineering Principles for Drug Delivery. (4) (Formerly numbered Biomedical Engineering C201.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 3B, Physics 1B. Application of engineering principles for designing and understanding delivery of therapeutics. Discussion of physics and mathematics required for understanding colloidal stability. Analysis of concepts related to both modeling and experiment of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C101. Letter grading. Mr. Kamei (F)

CM202. Basic Human Biology for Bioengineers I. (4) (Formerly numbered Biomedical Engineering CM202.) (Same as Physiology Science CM204.) Lecture, three hours; laboratory, one hour; outside study, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiology Science majors. Broad overview of basic biological activities and organization of human body in system (organ/to system) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of various experiments, as well as visits to biomedical facilities. Concurrently scheduled with course CM102. Letter grading. Mr. Grundfest (F)

CM203. Basic Human Biology for Bioengineers II. (4) (Formerly numbered Biomedical Engineering CM203.) (Same as Physiology Science CM203.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiology Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, musculoskeletal, endocrine, immune, urinary, reproductive). System-specific modeling/simulation of model systems (e.g., wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (e.g., anaesthesia monitoring devices) presented in context of system studies currently under way. Concurrently scheduled with course CM103. Letter grading. Mr. Grundfest (W)

CM204. Physical Chemistry of Biomacromolecules. (4) (Formerly numbered Biomedical Engineering C204.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 30A, Life Sciences 2, 3, 23L. To understand biological materials and design synthetic replacements, it is imperative to understand their physical chemistry. Biomacromolecules such as protein or DNA can be analyzed and characterized by applying fundamental principles of polymer physical chemistry. Integration of polymer structure and conformation, bulk physical properties, and solution thermodynamics and phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to biomedical systems involving biomacromolecules such as protein conformation, solvation of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C104. Letter grading. Mr. Grundfest (F)

C205. Biopolymer Chemistry and Bioconjugates. (4) (Formerly numbered Biomedical Engineering C205.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B. Application of engineering principles to one polymer to enhance its stability in serum. Wide variety of biocoujugates are used in delivery of pharmacueticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical linkage, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of some sample conjugate applications. Concurrently scheduled with course C105. Letter grading. Mr. Deming (W)

C206. Topics in Biophysics, Channels, and Membranes. (4) (Formerly numbered Biomedical Engineering C206.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4, 23L. Mathematically rigorous treatment of breadth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrohydrology. Basic physical principles govern electrostatics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C106. Letter grading. Mr. Schmidt (W)

C207. Polymer Chemistry for Bioengineers. (4) (Formerly numbered Biomedical Engineering C207.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 23L. Fundamental concepts of polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different polymerization schemes, including step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C107. Letter grading. Mr. Deming (W)

M214A. Digital Speech Processing. (4) (Formerly numbered Biomedical Engineering M214A.) (Same as Electrical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Electrical Engineering 113. Theory and implementation of computer speech signal processing. Mathematical models of human speech production and perception mechanisms, speech analysis/synthesis techniques. Include linear prediction, filterbank models, and applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Ms. Alwan (W)

M215. Biochemical Reaction Engineering. (4) (Formerly numbered Biomedical Engineering M215.) (Same as Chemical Engineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Electrical Engineering 103, and Mathematics 10B, 11B. Mathematical modeling of bioprocesses, biological systems, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. Letter grading. Mr. Liao (Sp)

M217. Biomedical Computing. (4) (Formerly numbered Biomedical Engineering M217.) (Same as Electrical Engineering M217.) Lecture, three hours; outside study, nine hours. Requisite: Electrical Engineering 114 or 211A. Optical imaging modalities in biomedicine. Overview of imaging modalities discussed briefly for comparison purposes. Letter grading.

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Formerly numbered Biomedical Engineering M219.) (Same as Biomedical Physics M219.) Lecture, three hours; discussion, one hour. Basic principles of magnetic resonance (MR), physics, and image formation. Emphasis on hardware, Bloch equations, analytic expressions, image contrast mechanisms, spin and gradient echoes, Fourier transform imaging methods, structure of pulse sequences, and various scanning parameters. Introduction to advanced techniques in rapid imaging, quantitative imaging, and spectroscopy. Letter grading.

220. Introduction to Medical Informatics. (2) (Formerly numbered Biomedical Engineering 220.) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to field. Emphasis on current research efforts, and future directions in research. Key issues in medical informatics to expose students to different application domains, such as information systems architectures, data-mining, information extraction and representations, information retrieval and visualization, health services research, telemedicine. Emphasis on current research endeavors.

221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) (Formerly numbered Biomedical Engineering 221.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to basic human biology, with particular emphasis on understanding anatomy and physiology through medical images. Topics relevant to acquisition, representation, and organization of biomedical knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastrointestinal, genitourinary, endocrine, and musculoskeletal systems. Introduction to basic imaging physics (magnetism, x-ray resonance imaging, computed tomography, ultrasound, computed radiography) to provide context for imaging modalities predominantly used to view human anatomy. Geared toward nonphysicians who require more formal understanding of human anatomy/physiology. Letter grading. Mr. El-Saden (F)

223A-223B-223C. Programming Laboratories for Medical and Imaging Informatics. (4-4-4) (Formerly numbered Biomedical Engineering 223A-223B-223C.) Lecture, two hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Programming laboratories to support coursework in other medical and imaging informatics core curriculum courses. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used in image processing and medical information system infrastructures. Letter grading. 223A. Requisites: Computer Science 31, 32, Program in Computing 20A, 20B. Course 223A is requisite to 223B, which is requisite to 223C. Integrated with topics presented in course M227 to reinforce concepts presented with practical experience. Projects focus on understanding medical networking issues. Also integrated with topics presented in course M228 to reinforce concepts presented with practical experience. Projects focus on medical image manipulation and decision support systems. 223C. Requisite: course 223B. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used to extract meaningful features from medical text and imaging data and visualize results. Integrated with topics presented in courses 224B and 225B to reinforce concepts presented with practical experience. Projects focus on medical information retrieval, knowledge representation and visualization. Mr. Meng (W/Sp)

224A. Physics and Informatics of Medical Imaging. (4) (Formerly numbered Biomedical Engineering 224A.) Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to basic imaging physics and imaging informatics for nonphysicists. Overview of core imaging modalities: X-ray, computed tomography (CT), and magnetic resonance (MR). Topics include image localization, and quantization. Image representation and analysis techniques such as Markov random fields,
spatial characterization (atlases), denoising, energy representations, and clinical imaging workstation design. Provides basic understanding of issues related to basic medical image acquisition and analysis. Current research efforts with focus on clinical applications and new types of information made available through these modalities. Letter grading. Mr. Morioka (W)

M224. Advances in Imaging Informatics. (4) (Formerly numbered Biomedical Engineering M224.) Lecture, four hours; outside study, eight hours. Requisite: course CM202. Overview of issues related to medical decision making and decision-making software packages to familiarize students with current tools. Letter grading. Mr. Kangarloo (W)

C231. Nanopore Sensing. (4) (Formerly numbered Biomedical Engineering C231.) Lecture, four hours; discussion, two hours; laboratory, one hour. Requisites: courses 100, 120, Life Sciences 2, 3, 23L, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artificial or protein nanopore based on measurements of fluctuating ionic conductance through artificial or protein nanopore. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ionic conductance through pores and GHK equation, patch clamp and single-channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C213. Mr. Schmidt (F)

CM240. Introduction to Biomechanics. (4) (Formerly numbered Biomedical Engineering CM240) (Same as Chemical and Aerospace Engineering CM240.) Lecture, four hours; discussion, two hours; laboratory, two hours. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading. Mr. Gupta (W)

CM245. Molecular Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM245) (Same as Chemical Engineering CM245.) Lecture, four hours; discussion, one hour; outside study, eight hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics technologies, evolution of the human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading. Mr. Liao (F)

C247. Applied Tissue Engineering: Clinical and Industrial Perspectives. (4) (Formerly numbered Biomedical Engineering C247.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods (platelet-derived), and physiological and chemical biological testing. Case studies include skin and artificial bone, cartilage, blood vessels, neurotissue engineering, and liver. Kidney extracellular matrix. Partial differential equations. Tissue engineering. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C147. Letter grading. Mr. Wu (F)

M248. Introduction to Biological Imaging. (4) (Formerly numbered Biomedical Engineering M248.) (Same as Biomedical Physics M248 and Pharmacology M248.) Lecture, four hours; outside study, one hour; outside study, seven hours. Exploration of role of biological imaging in modern biology and medicine, including imaging physics, instrumentation, image processing, and applications of imaging for range of modalities. Practical experience provided through seminars and imaging laboratories. Letter grading. Concurrently scheduled with course CM150. Letter grading. Mr. Judy (W)

M250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Formerly numbered Biomedical Engineering M250B.) (Same as Electrical Engineering CM250B and Mechanical and Aerospace Engineering CM250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to microfabrication process. Letter grading. Mr. Judy (Sp)

CM250L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Formerly numbered Biomedical Engineering CM250L.) (Same as Electrical Engineering CM250L and Mechanical and Aerospace Engineering CM250L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM250A, Chemistry 20A, 20B, Physics 1A, 1B, 1C, 4A, 4BL. Hands-on introduction to microtechnologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM150L. Letter grading. Mr. Judy (F)

M252. Microelectromechanical Systems (MEMS) Design. Physics and Design. (4) (Formerly numbered Biomedical Engineering M252.) (Same as Electrical Engineering CM252 and Mechanical and Aerospace Engineering CM252.) Lecture, four hours; outside study, eight hours. Enforced prerequisite: course CM140 or CM250A. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design. Letter grading. Mr. Wu (Sp)


M260. Neuroengineering. (4) (Formerly numbered Biomedical Engineering M260.) (Same as Electrical Engineering M255 and Neuroscience M260.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Chemis 32A, Physics 1B or 6B. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity, electrolythology (action potentials, local field potentials, EEG, ECOG), intracellular and extracellular...
lary recording, microelectrode technology, neural signal processing (neural signal frequency bands, filtering, spike sorting, and neuron artifact removal), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading.

Mr. Judy (Sp)

M261A-M261B-M261C. Evaluation of Research Literature in Biomedical Engineering. (2 to 4) (Formerly numbered Biomedical Engineering M261A-M261B-M261C.) (Same as Electrical Engineering M265A-M265B-M265C and Neuroscience M261A-M261B-M261C.) Lecture, three hours; outside study, seven hours. Requisite: course C270. Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: Chemistry 20A, 20B, and 20L. Materials Science 104. Engineering materials used in medicine and dentistry and materials for design and development of novel drug delivery systems and compounds used in delivery systems. Introduction to biomaterials with special emphasis on their surface and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and release. Concurrently scheduled with course C170. Letter grading.

Mr. Grundfest (W)

C270. Energy-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C270.) Lecture, four hours; outside study, nine hours. Requisite: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications. Shuttling electrons and understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C170. Letter grading. Mr. Grundfest (F)

C270L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) (Formerly numbered Biomedical Engineering C270L.) Laboratory, four hours; outside study, two hours. Corequisite: course C270. Introduction and experimental techniques used in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissue/tissue phantom, making tissue phantoms, determination of optical properties of different tissues, techniques of temperature distribution measurements. Concurrently scheduled with course C170L. Letter grading.

Mr. Fisher (Sp)

C271. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) (Formerly numbered Biomedical Engineering C271.) Lecture, four hours; outside study, eight hours. Requisite: course C270. Designed for physical scientists, engineers, and students interested in laser-tissue interaction. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biologic media. Concurrently scheduled with course C171L. Letter grading. Mr. Grundfest (W)

C272. Design of Minimally Invasive Surgical Tools. (4) (Formerly numbered Biomedical Engineering C272.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: Chemistry 30B, Life Sciences 2, 3, 23L, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biopsy devices, laparoscopic tools, cardiac and peripheral vascular devices, interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and incorporation of design into consideration of development of new and novel devices. Concurrently scheduled with course C172L. Letter grading.

Mr. Grundfest (F)

CM278. Introduction to Biomaterials. (4) (Formerly numbered Biomedical Engineering C278.) (Same as Materials Science CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L.
M296C. Advanced Topics and Research in Bio- 
medical Systems Modeling and Computing. (4) 
(Formerly numbered Biomedical Engineering 
M296C.) Lecture, four hours; outside study, 
eight hours. Research and study on special topics 
in biomedical systems modeling and comput- 
ing. Requisite: course M296B. Letter grading.

M296D. Introduction to Computational Cardiolo- 
gy. (4) Lecture, four hours; outside study, eight hours. 
Theory of AP propagation in one-dimensional and 
two-dimensional cardiac tissue. Theory of 
computational stability. Letter grading.

Mr. DiStefano (Sp)

M298. Special Studies in Bioengineering. (4) 
(Formerly numbered Biomedical Engineering 
M298.) Lecture, four hours; outside study, eight hours. 
Study of selected topics in bioengineering taught by 
faculty members. May be repeated for credit. Letter grading.

Mr. Kogan (FSp)

299. Seminar: Bioengineering Topics. (2) 
(Formerly numbered Biomedical Engineering 
299.) Seminar, two hours; outside study, four hours. 
Offered to graduate bioengineering students. 
Presentations by faculty members on current 
research. Seminars may cover technical and 
research topics in areas of interest to students. 
Letter grading.

Mr. Wu (FW,Sp)

375. Teaching Apprentice Practicum. (4) 
(Formerly numbered Biomedical Engineering 
375.) Seminar, two hours; outside study, four hours. 
Teaching apprenticeship under the supervision of 
a faculty member. Letter grading.

Mr. DiStefano (Sp)

597B. Preparation for Ph.D. Preliminary Examina- 
tions. (2 to 16) Tutorial, to be arranged. Limited to graduate 
bioengineering students. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Exam- 
ination. (2 to 16) Tutorial, to be arranged. Limited to graduate 
bioengineering students. Preparation for oral 
qualifying examination, including preliminary re- 

598. Research for and Preparation of M.S. Thesis. 
(2 to 12) Tutorial, to be arranged. Limited to graduate 
bioengineering students. Required of all graduate 
bioengineering students. S/U grading.

599. Research for and Preparation of Ph.D. Dis- 
sertation. (2 to 16) Tutorial, to be arranged. Limited to graduate 
bioengineering students. Usually taken after 
other students have been advanced to candidacy. S/U grading.
mal vapor deposition, plasma processing, and polymer engineering. Students are trained in the fundamental principles of these fields while acquiring sensitivity to society's needs—a crucial combination needed to address the challenge of continued industrial growth and innovation in an era of economic, environmental, and energy constraints.

The undergraduate curriculum leads to a B.S. in Chemical Engineering and includes the standard core curriculum, as well as biomedical engineering, biomolecular engineering, environmental engineering, and semiconductor manufacturing engineering options. The department also offers graduate courses and research leading to M.S. and Ph.D. degrees. Both graduate and undergraduate programs closely relate teaching and research to important industrial problems.

Undergraduate Mission and Program Objectives

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The mission of the undergraduate program is to educate future leaders in chemical and biomolecular engineering who effectively combine their broad knowledge of physics, chemistry, biology, and mathematics with their engineering analysis and design skills for the creative solution of problems in chemical and biological technology and for the synthesis of innovative (bio)chemical processes and products. This goal is achieved by producing chemical and biomolecular engineering alumni who (1) draw readily on a rigorous education in mathematics, physics, chemistry, and biology in addition to the fundamentals of chemical engineering to creatively solve problems in chemical and biological technology, (2) incorporate social, ethical, environmental, and economical considerations, including the concept of sustainable development, into chemical and biomolecular engineering practice, (3) lead or participate successfully on multidisciplinary teams assembled to tackle complex multifaceted problems that may require implementation of both experimental and computational approaches and a broad array of analytical tools, and (4) pursue graduate study and achieve an M.S. or Ph.D. degree in the sciences and engineering and/or achieve success as professionals in chemical and biomolecular engineering as well as related fields, including business, medicine, and environmental protection.

Undergraduate Study

The Chemical Engineering major is a designated capstone major. The capstone project requires students to first work individually and learn how to integrate chemical engineering fundamentals taught in prior required courses; they then work in groups to produce a paper design of a realistic chemical process using appropriate software tools. Graduates should be able to design a chemical or biological system, component, or process that meets technical and economical design objectives, with consideration of environmental, social, and ethical issues, as well as sustainable development goals. In addition, they should be able to apply their knowledge of mathematics, physics, chemistry, biology, and chemical and biological engineering to analysis and design of chemical and biochemical processes and products; function on multidisciplinary teams; identify, formulate, and solve complex chemical and biological engineering problems; and communicate effectively, both orally and in writing.

Chemical Engineering B.S.

Capstone Major

The chemical engineering curricula provide a high quality, professionally oriented education in modern chemical engineering. The biomedical engineering, bio-molecular engineering, environmental engineering, and semiconductor manufacturing engineering options provide students an opportunity for exposure to a subfield of chemical and biomolecular engineering. In all cases, balance is sought between engineering science and practice.

Chemical Engineering Core Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomedical elective course (4 units) from Chemical Engineering C115, C121, C124, C125, C127, C135, or CM145 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Biomedical Engineering Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Computer Science 31; Life Sciences 2, 3, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 104A, 104D, 104DL, 107, 109, C115, C125, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomedical elective course (4 units) from Chemical Engineering C124, CM127, C135, or CM145 (course CM145 is recommended; another chemical engineering
selective may be substituted with approval of the faculty adviser).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Environmental Engineering Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, Atmospheric and Oceanic Sciences 104, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and two elective courses (8 units) from Chemical Engineering 113, C118, C119, C121, C135, C140 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Semiconductor Manufacturing Engineering Option

Preparation for the Major

Required: Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104C, 104CL, 106, 107, 109, C116, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one elective course (4 units) from Materials Science and Engineering 104, 120, 121, 122, or 150 plus one elective course (4 units) from Electrical Engineering 2, 100, 121B, 123A, or 123B.

A program of study that encompasses these requirements must be submitted to the departmental Student Affairs Office for approval before the end of the student’s second term in residence.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Semiconductor Manufacturing

The requirements for the M.S. degree in the field of semiconductor manufacturing are 10 courses (44 units) and a minimum 3.0 grade-point average overall and in the graduate courses. Students are required to take Chemical Engineering 104C/104CL, C216, 270, 270R, Electrical Engineering 123A, Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical engineering or materials science and engineering electives must be selected, with a minimum of two at the 200 level. A total of at least five graduate (200-level) courses is required. Approved elective courses include Chemical Engineering C214, C218, C219, 223, C240, Electrical Engineering 124, 221A, 221B, 233, Materials Science and Engineering 210, 223.

Courses taken by students who are not enrolled in the semiconductor manufacturing field may not be applied toward the 10-course requirement for the degree. A program of study encompassing the course requirements and/or substitutions must be submitted to the graduate adviser for approval before the end of the first term in residence.

Field Experience. Students may take Chemical Engineering 270R in the field, working at an industrial semiconductor fabrication facility. This option must meet all course requirements and must be approved by the graduate adviser and the industrial sponsor of the research.

Comprehensive Examination Plan

The comprehensive examination plan is not available for fields other than semiconductor manufacturing.
For the semiconductor manufacturing field, when all coursework is completed, students should enroll in Chemical Engineering 597A to prepare for the comprehensive examination, which tests their knowledge of the engineering principles of semiconductor manufacturing. In case of failure, the examination may be repeated once with the consent of the graduate adviser.

**Thesis Plan**
Consult the graduate adviser. The thesis plan is not available for the semiconductor manufacturing field.

**Chemical Engineering Ph.D.**

**Major Fields or Subdisciplines**
Consult the department.

**Course Requirements**
All Ph.D. students must take six courses (24 units), including Chemical Engineering 200, 210, and 220. Two additional courses must be taken from those offered by the Chemical and Biomolecular Engineering Department. The third course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. All of these units must be in letter-graded 200-level courses. Students are encouraged to take more courses in their field of specialization. The minor field courses should be selected in consultation with the research adviser. A 3.33 grade-point average in graduate courses is required. A program of study to fulfill the course requirements must be submitted for approval to the departmental Student Affairs Office no later than one term after successful completion of the preliminary oral examination.

All Ph.D. students are required to enroll in the seminar, Chemical Engineering 299, during each term in residence. For information on completing the Engineer degree, see Engineering Schoolwide Programs.

**Written and Oral Qualifying Examinations**
Academic Senate regulations require all doctoral students to complete and pass University written and oral qualifying examinations prior to doctoral advancement to candidacy. Under Senate regulations the University Oral Qualifying Examination is open only to students and appointed members of their doctoral committees. In addition to University requirements, some graduate programs have other pre candidacy examination requirements. What follows are the requirements for this doctoral program.

All entering Ph.D. students are required to undergo a preliminary oral examination (POE) normally scheduled at the beginning of Fall Quarter. This evaluation by a faculty committee assesses student understanding of chemical and biomolecular engineering fundamentals in the areas of the required core graduate courses. The POE outcome consists of a recommendation of a course plan for the students that ultimately can lead to successful completion of the course requirements for the Ph.D. degree.

After completion of the required courses for the degree, students must pass the written and oral qualifying examinations. These examinations focus on the dissertation research and are conducted by a doctoral committee consisting of at least four faculty members nominated by the department in accordance with University regulations. Three members, including the chair, are inside members and must hold faculty appointments in the department. The outside member must be a UCLA faculty member in another department. Students are required to have a 3.33 grade-point average in graduate coursework to be eligible to take these examinations.

The written qualifying examination consists of a dissertation research proposal that provides a clear description of the problem(s) considered, a literature review of the current state of the art, and a detailed explanation of the research plan that is to be followed to solve the problem(s). Students normally submit their dissertation research proposals to their doctoral committees before the end of Winter Quarter of the second year in academic residence.

The University Oral Qualifying Examination consists of an oral defense of the dissertation research proposal and is administered by the doctoral committee. The written research proposal must be submitted to the committee at least two weeks prior to the oral examination to allow the members sufficient time to evaluate the work.

**Facilities**

**Biomolecular Engineering Laboratories**
The Biomolecular Engineering laboratories are equipped for cutting-edge genetic, biomolecular, and cellular engineering teaching and research. Facilities and equipment include (1) bioreactors, (2) fluorescence microscopy, (3) real-time PCR thermocycler, (4) UV-visible and fluorescence spectrophotometers, (5) HPLC and LC-mass spectrometer, (6) aerobic and anaerobic bioreactors from bench top to 100-liter pilot scale, (7) protein purification facility, (8) potentiosatt/galvanostat and impedance analyzer for electroenzymology, (9) membrane extruder and multangle laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and (10)
phosphorimager for biochemical assays involving radiolabeled compounds.

Microbial cells are genetically and metabolically engineered to produce compounds that are used as fuel, chemicals, drugs, and food additives. Novel gene-metabolic circuits are designed and constructed in microbial cells to perform complex and non-native cellular behavior. These designer cells are cultured in bioreactors, and intracellular states are monitored. Such investigations are coupled with genomic and proteomic efforts, and mathematical modeling, to achieve system-wide understanding of the cell.

Protein engineering is being used to generate completely novel compounds that have important pharmaceutical value. Bacteria are being custom-designed to synthesize important therapeutic compounds that have anticancer, cholesterol-lowering, and/or antibiotic activities. Biosensors are being micromachined for detecting neurotransmitters in vivo. New biosensing schemes also are being invented for the detection of endocrine disrupting chemicals in the environment and for the high-throughput screening of drug candidates. Naturally occurring protein nanocapsules are being redesigned at the genetic level for applications in drug delivery and materials synthesis. Finally, the enzymology of extremely thermophilic microbes is being explored for applications in specialty chemical synthesis.

**Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory**

The Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory is equipped with advanced research tools for experimental and computational studies in chemical kinetics, catalytic materials, and combustion, including quadrupole mass spectrometer (QMS) systems to sample reactive systems with electron impact and photoionization capabilities; several fully computerized gas chromatograph/mass spectrometer (GC/MS) systems for gas analysis; fully computerized array channel microreactors for catalyst discovery and optimization; several flat premixed and diffusion flame burners and flow reactors to study combustion and other fast reactions; a laser photoionization (LP) time-of-flight (TOF) mass spectrometer for the ultra-sensitive, real-time detection of trace pollutants in the gas phase; a gravimetric microbalance to study heterogeneous reactions; and several state-of-the-art supermicro workstations for numerical investigations in fluid mechanics, detailed chemical kinetic modeling, and computational quantum chemistry.

**Electrochemical Engineering and Catalysis Laboratories**

With instrumentation such as rotating ring-disk electrodes, electrochemical packed-bed flow reactors, gas chromatographs, potentiostats, and function generators, the Electrochemical Engineering and Catalysis Laboratories are used to study metal, alloy, and semiconductor corrosion processes, electro-deposition and electroless deposition of metals, alloys, and semiconductors for GMR and MEMS applications, electrochemical energy conversion (fuel cells) and storage (batteries), and bioelectrochemical processes and biomedical systems.

The electroorganic synthesis facility is for the development of electrochemical processes to transform biomass-derived organic compounds into useful chemicals, fuels, and pharmaceuticals. The catalysis facility is equipped to support various types of catalysis projects, including catalytic hydrocarbon oxidation, selective catalytic reduction of NOx, and Fischer-Tropsch synthesis.

**Electronic Materials Processing Laboratory**

The Electronic Materials Processing Laboratory focuses on the synthesis and patterning of multifunctional complex oxide films and nanostructures with tailored electronic, chemical, thermal, mechanical, and biological properties. Experimental and theoretical studies are combined to understand the process chemistry and surface kinetics in atomic layer deposition, plasma etching and deposition processes, gas-phase surface functionalization, and solution phase synthesis. Novel devices including advanced microelectronics, optoelectronics, chemical sensors, and energy storage devices are realized at nano-dimensions as the technologies become more enabling based on these fundamental studies.

The laboratory is equipped with a state-of-the-art advanced rapid thermal processing facility with in-situ vapor phase processing and atomic layer deposition capabilities; advanced plasma processing tools including thin film deposition and etching; and diagnostics including optical emissions spectroscopy, Langmuir probe, and quadrupole mass spectrometer; a surface analytical facility including X-ray photoelectron spectroscopy, Auger electron spectroscopy, ultra-violet photoelectron spectroscopy, reflection high energy electron diffraction, spectroscopic ellipsometry, photoluminescence, and infrared spectroscopy; and a complete set of processing tools available for microelectronics and MEMS fabrication in the Nanoelectronic Research Facility. With the combined material characterization and electronic device fabrication, the reaction kinetics including composition and morphology, and the electrical property of these materials can be realized for applications in the next generation electronic devices and chemical or biological MEMS.

**Materials and Plasma Chemistry Laboratory**

The Materials and Plasma Chemistry Laboratory is equipped with state-of-the-art instruments for studying the molecular processes that occur during chemical vapor deposition (CVD) and plasma processing. CVD is a key technology for synthesizing advanced electronic and optical devices, including solid-state lasers, infrared, visible, and ultraviolet detectors and emitters, solar cells, heterojunction bipolar transistors, and high-electron mobility transistors. The laboratory houses a commercial CVD reactor for the synthesis of III-V compound semiconductors. This tool is interfaced to an ultra-high vacuum system equipped with scanning tunneling microscopy, low-energy electron diffraction; infrared spectroscopy and X-ray photoelectron spectroscopy. This apparatus characterizes the atomic structure of compound semiconductor heterojunction interfaces and determines the kinetics of CVD reactions on these surfaces.

The atmospheric plasma laboratory is equipped with multiple plasma sources and state-of-the-art diagnostic tools. The plasmas generate, at low temperature, beams of atoms and radicals well-suited for surface treatment, cleaning, etching, deposition, and sterilization. Applications are in the biomedical, electronics, and aerospace fields. The laboratory is unique in that it characterizes the reactive species generated in atmospheric plasmas and their chemical interactions with surfaces.

**Nanoparticle Technology and Air Quality Engineering Laboratory**

Modern particle technology focuses on particles in the nanometer (nm) size range with applications to air pollution control and commercial production of fine particles. Particles with diameters between 1 and 100 nm are of interest both as individual particles and in the form of aggregate structures. The Nanoparticle Technology and Air Quality Engineering Laboratory is equipped with...
instrumentation for online measurement of aerosols, including optical particle counters, electrical aerosol analyzers, and condensation particle counters. A novel low-pressure impactor designed in the laboratory is used to fractionate particles for morphological analysis in size ranges down to 50 nm (0.05 micron). Also available is a high-volumetric flow rate impactor suitable for collecting particulate matter for chemical analysis. Several types of specially designed aerosol generators are also available, including a laser ablation chamber, tube furnaces, and a specially designed aerosol microreactor. Concern with nanoscale phenomena requires the use of advanced systems for particle observation and manipulation. Students have direct access to modern facilities for transmission and scanning electron microscopy. Located near the laboratory, the Electron Microscopy facilities staff provide instruction and assistance in the use of these instruments. Advanced electron microscopy has recently been used in the laboratory to make the first systematic studies of atmospheric nanoparticle chain aggregates. Such aggregate structures have been linked to public health effects and to the absorption of solar radiation. A novel nanostructure manipulation device, designed and built in the laboratory, makes it possible to probe the behavior of nanoparticle chain aggregates of a type produced commercially for use in noncomposite materials; these aggregates are also released by sources of pollution such as diesel engines and incinerators.

Polymer and Separations Research Laboratory
The Polymer and Separations Research Laboratory is equipped for research on membranes, water desalination, adsorption, chemical sensors, polymerization kinetics, surface engineering with polymers and the behavior of polymeric fluids in confined geometries. Instrumentation includes a high resolution multiprobe Atomic Force Microscope (AFM) and a quartz crystal microbalance system for membrane and sensor development work. An atmospheric plasma surface structuring system is available for nano-structuring ceramic and polymeric surfaces for a variety of applications that include membrane performance enhancement and chemical sensor arrays. Analytical equipment for polymer characterization includes several high-pressure liquid chromatographs for size exclusion chromatography equipped with different detectors, including refractive index, UV photodiode array, conductivity, and a photodiode array laser light scattering detector. The laboratory has a research-grade FTIR with a TGA interface, a thermogravimetric analysis system, and a dual column gas chromatograph. Equipment for viscometric analysis includes high- and low-pressure capillary viscometer, narrow gap cylindrical couette viscometer, cone-and-plate viscometer, intrinsic viscosityviscometer system and associated equipment. Flow equipment is also available for studying fluid flow through channels of different geometries (e.g., capillary, slit, porous media). The evaluation of polymeric and novel ceramic-polymer membranes developed in the laboratory, is made possible with reverse osmosis, pervaporation, and cross-flow ultrafiltration systems equipped with online detectors. Studies of high recovery membrane desalination are carried out in a membrane concentrator/crystallizer system. Resin sorption and regeneration studies can be carried out with a fully automated system.

Process Systems Engineering Laboratory
The Process Systems Engineering Laboratory is equipped with state-of-the-art computer hardware and software used for the simulation, design, optimization, control, and integration of chemical processes. Several personal computers and workstations, as well as an 8-node dual-processor cluster, are available for teaching and research. SEASnet and campuswide computational facilities are also available to the laboratory’s members. Software for simulation and optimization of general systems includes MINOS, GAMS, MATLAB, CPLEX, and LINDO. Software for simulation of chemical engineering systems includes HYSYS for process simulation and CACHE-FUJITSU for molecular calculations. UCLA-developed software for heat/power integration and reactor network attainable region construction are also available.

Faculty Areas of Thesis Guidance

Professors
Jane P. Chang, Ph.D. (MIT, 1998)
Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry
Panagiotis D. Christofides, Ph.D. (Minnesota, 1996)
Process modeling, dynamics and control, computational and applied mathematics
Yoram Cohen, Ph.D. (Delaware, 1981)
Separation processes, graft polymerization, surface nanostructurung, macromolecular dynamics, pollutant transport and exposure assessment
James F. Davis, Ph.D. (Northwestern, 1981)
Intelligent systems in process, control operations and design, decision support, management of abnormal situations, data interpretation, knowledge databases, pattern recognition
Robert F. Hicks, Ph.D. (UC Berkeley, 1984)
Chemical vapor deposition and atmospheric plasma processing
Louis J. Ignarro, Ph.D. (Minnesota, 1966)
Regulation and modulation of NO production
James C. Liao, Ph.D. (Wisconsin, Madison, 1987)
Metabolic engineering, synthetic biology, biocatalysis
Yunfeng Lu, Ph.D. (U New Mexico, 1998)
Semiconductor manufacturing and nanotechnology
Vasilios I. Manousiouthakis, Ph.D. (Rensselaer, 1986)
Process systems engineering: modeling, simulation, design, optimization, and control
Harold G. Moneta, Ph.D. (North Carolina State, 1987)
Biochemical engineering, biosensors, nanotechnology
Selim M. Senkan, Ph.D. (MIT, 1977)
Reaction engineering, combinatorial catalysis, combustion, laser photolization, real-time detection, quantum chemistry
Yi Tang, Ph.D. (Caltech, 2002)
Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibiotics/antitumor products

Professors Emeriti
Eldon L. Knuth, Ph.D. (Caltech, 1953)
Molecular dynamics, thermodynamics, combustion, applications to air pollution control and combustion efficiency
Ken Nobe, Ph.D. (UCLA, 1956)
Electrochemistry, corrosion, electrochemical kinetics, electrochemical energy conversion, electrodeposition of metals and alloys, electrochemical treatment of toxic wastes, bioelectrochemistry
William D. Van Vorst, Ph.D. (UCLA, 1953)
Chemical engineering: thermodynamics, energy conversion, alternative energy systems, hydrogen, alcohol, and alcohol-fueled engines
A.R. Frank Wanzzu, Ph.D. (UC Berkeley, 1963)
Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer

Associate Professor
Tatiana Segura, Ph.D. (Northwestern, 2004)
Gene therapy, tissue engineering, substrate-mediated non-viral DNA delivery

Assistant Professor
Georssimos Orkoulas, Ph.D. (Cornell, 1998)
Molecular simulation, critical phenomena in ionic fluids, thermodynamics of complex fluids

Lower Division Courses
2. Technology and Environment. (4) Lecture, four hours; outside study, eight hours. Natural and anthropogenic flows of materials at global and regional scales. Case studies of natural cycles include global warming (CO2 cycles), stratospheric ozone depletion (chlorine and ozone cycles), and global nitrogen cycles. Flow of materials in industrial economies compared and contrasted with natural flows; presentation of lifecycle methods for evaluating environmental impact of products and processes. P/NP or letter grading. Mr. Manousiouthakis (Not offered 2012-13)
10. Introduction to Chemical and Biomolecular Engineering. (1) Lecture, one hour, outside study, two hours. General introduction to field of chemical and biomolecular engineering. Description of how chemical and biomolecular engineering analysis and
design skills are applied for creative solution of cur- rent technological problems in production of micro- electronics and integration of chemical plants. It is impera- tive for students to develop awareness of fundamental environmental impact, application of nanotechno- logy to chemical sensing, and genetic level design of recombinant microbes for chemical synthesis. Let- ter grading.

Mr. Liao (F) 19. Finer Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower-division students under guidance of faculty mentor. Students must be in good academic standing and en- rolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

100. Fundamentals of Chemical and Biomole- cular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20B, 20L, Mathematics 32B (may be taken concurrently), Physics 1A. Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programming in MATLAB. Letter grading. Mr. Manousiouthakis (F) 101A. Transport Phenomena I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mathematics 33A, 33B. Corequi- site: course 105. Introduction to analysis of fluid flow in chemical, biological, materials, and molecular processes. Fundamentals of momentum transport, Newton- ton law of viscosity, mass and momentum conserva- tion in laminar and turbulent flows, incompressible and re- sistance flow systems. Letter grading. Mr. Senkan (F) 101B. Transport Phenomena II: Heat Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Introduction to analysis of heat transfer in chemical, biological, materials, and molecular processes. Fun- damentals of thermal energy transport, molecular level heat transfer in gases, liquids, and solids, forced and free convection, radiation, and engineering analysis of heat transfer in process systems. Letter grading. Mr. Segura (W) 102A. Thermodynamics I (Lecture). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to thermodynamics of chemical and bio- logical processes. Work, energy, heat, and first law of thermodynamics. Second law, extremum principles, entropy, and free energy. Ideal and real gases, prop- erty evaluation. Thermodynamics of flow systems. Applications of first and second laws in biological pro- cesses and living organisms. Letter grading. Mr. Hicks (F) 102B. Thermodynamics II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102A. Fundamentals of classical and statistical thermodynamics in chemical and bio- logical sciences. Phase equilibria in single and multi- component systems. Thermodynamics of ideal and nonideal solutions. Chemical reaction equilibria. Sta- tistical ensembles and partition functions. Statistical thermodynamics of ideal gases. Interfacial interac- tions and liquid state. Thermodynamics of poly- mers and biological macromolecules. Letter grading. Mr. Orkoulas (Sp) 103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101B. Application of principles of heat, mass, and momentum transport to de- sign and operation of separation processes such as distillation, gas absorption, filtration, and reverse os- mosis. Letter grading. 104A/104AL. Introduction to Biomolecular Engineering Laboratory I. (4) (Formerly numbered 104AL.) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite: course 100. Corequisite: course 104C. Concurrent requisite course 102B. Not open for credit to students with credit for former course 104AL. Investigation of basic transport phe- nomena in 10 predetermined experiments, collection of data for student individually written technical reports and group presentations. Design and performance of one original experimental study involving transport, separation, or another aspect of chemical and biomolecular engineering. Basic statis- tics: mean, standard deviation, confidence limits, comparison of two means and of multiple means, sin- gle and multiple variable linear regression, and brief introduction to factorial design of experiments. Oral and poster presentations. Technical writing of sec- tions of technical reports and their contents; writing clearly, concisely, and consistently; importance of word choice and choice of multicultural engi- neering environment and of following required for- matting. Letter grading. Mr. Monbouquette (W,Sp) 104B. Chemical and Biomolecular Engineering Laboratory II. (6) Lecture, four hours; laboratory, eight hours; outside study, two hours. Requisites: courses 101C, 103, 104A. Course consists of experiments in chemical engineering unit operations, each of two weeks duration. Students present their results both written and orally. Written report includes sections on theory, experimental pro- cedures, scaleup and process design, and error anal- ysis. Letter grading. Mr. Senkan (F,W) 104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Requisite: course 101C. Corequisite: course 104CL. Basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor de- vices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metalization, and statistical design of experiments and error analysis. Presentation of student results in both written and oral form. Letter grading. Mr. Hicks (Sp) 104CL. Semiconductor Processing Laboratory. (3) Laboratory, six hours; outside study, one hour. Requisite: course 101C. Corequisite: course 104C. Series of experiments that emphasize basic engi- neering principles of semiconductor unit operations, including fabrication and characterization of semiconduc- tor devices. Investigation of processing steps used to make CMOS devices, including wafer clean- ing, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, and metalization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Mr. Hicks (Sp) 104D. Molecular Biotechnology Laboratory: From Gene to Product. (2) Lecture, two hours; outside study, four hours. Requisites: courses 101C, 102B, Enforced corequisite: course 104DL. Integration of molecular and engineering techniques in modern bio- technology. Cloning of protein-coding gene into plasmid, transformation, construction into E. coli, produc- tion of gene product in bioreactor, downstream proc- essing of bioreactor broth to purify recombinant protein, and characterization and purification. Letter grading. Ms. Segura, Mr. Tang (F,W) 104DL. Molecular Biotechnology Laboratory: From Gene to Product. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 101C, 102B, Enforced corequisite: course 104CL. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid, transformation of construct into E. coli, produc- tion of gene product in bioreactor, downstream processing of bioreactor broth to purify recombinant protein, and characterization and purification. Letter grading. Mr. Orkoulas (Sp) 105. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101C, 103 or C125, 106 or C115. Principles of dynamics modeling and control, and chemical process engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for pur- poses of designing chemical processes. Letter grading. Mr. Pang (W) 108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Computer Science 31. Introduction to some mathematical and computing methods to chemical engineering design problems; use of simulation pro- grams as automated method of performing steady state material and energy balance calculations. Let- ter grading. Mr. Pang (Sp) 109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Computer Science 31. Corequisite: course 101A. Numerical methods for computa- tion of solution of systems of linear or non- linear algebraic equations, ordinary differential equa- tions, and partial equations. Chemical and biomolecu- lular engineering examples used throughout to illus- trate application of these methods. Use of MATLAB as platform (programming environment) to write pro- grams based on numerical methods to solve various problems arising in chemical engineering. Letter grading. Mr. Orkoulas (F) 110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102B. Principles and engineering applications of statistical and phenomenological thermal dynamics. Determination of parameter function in terms of simple molecular models and spectroscopic data; nonideal gases; phase transitions and adsorp- tion; nonequilibrium thermodynamics and coupled transport processes. Letter grading. (Not offered 2012-13) C111. Cryogenics and Low-Temperature Process- es. (4) Lecture, four hours; discussion, one hour; out- side study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryogenics engineering science pertaining to industrial low-temperature processes. Basic principles and analysis of systems and devices used for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosys- tems and other special conditions. Concurrently scheduled with course C211. Letter grading. Mr. Yuan (F) C112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A. Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Polymers in biotechnology and in microelectronics. Concurrently scheduled with course C212. Letter grading. Mr. Lu (W)
113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Requisites: courses 101C, 102B. Integrative approach to air pollution, including concentrations of atmospheric pollutants, air pollution standards, air pollution sources and control technology, and relationship of air quality to emission sources. Links air pollution to multimedia environmental systems. Mr. Segura (F). Letter grading. (Not offered 2012-13)

C114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C, 102B. Integrated approach to air pollution, including concentrations of atmospheric pollutants, air pollution standards, air pollution sources and control technology, and relationship of air quality to emission sources. Links air pollution to multimedia environmental systems. Mr. Segura (F). Letter grading. (Not offered 2012-13)

C124. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 3, 23L. Introduction to design and synthesis of biomaterials for regenerative medicine, in vitro cell culture, and drug delivery. Biological principles of cellular microenvironment and design of extracellular matrix analogs using biomedical approaches and molecular approaches and advanced techniques for growth factor, and DNA and sRNA delivery as therapeutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224. Letter grading. (Not offered 2012-13)

C125. Bioseparations and Bioprocess Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently scheduled with course CM225. Letter grading. Mr. Monbouquette (Sp).

CM127. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM127.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 153A, Life Sciences 3, 23L. Engineering microorganisms for complex phenotype is combined with classical engineering approaches and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biology, design, chemical engineering, and information technology. The class explores the use of modern methods for cellular biology, genetic engineering, metabolism, and synthetic biology for the design and construction of metabolic pathways that can be used to produce advanced biofuels. Letter grading. Mr. Nobe (F).

C115. Biochemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: Chemistry 113A. Introduction to surfaces and interfaces of engineering materials, particularly catalytic surface and thin films for solid-state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of surfaces and interfaces, and applications. Examination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course CM126. Letter grading. Mr. Lu (Sp).


C121. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, theory of separation processes at atomic and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of electronic and microscopic techniques and models of membrane transport (flux and selectivity). Examples provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C221. Letter grading. Mr. Cohen (Not offered 2012-13)

C122. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Polymers in biomedical applications and in microelectronics. Concurrently scheduled with course C112. Letter grading. Mr. Cohen, Mr. Lu (W).

C124. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and biological systems. Primary emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal and semiconductor surface finish, passivity, electrodeposition, electroless deposition, batteries and fuel cells, electrosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. (Not offered 2012-13)

C212. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Polymers in biomedical applications and in microelectronics. Concurrently scheduled with course C112. Letter grading. Mr. Cohen, Mr. Lu (W).
CM215. Biochemical Reaction Engineering. (4) (Same as Bioengineering M215.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 101C. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological systems. May be concurrently scheduled with course C115. Letter grading. Mr. Monbouquette (F)

C216. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: Chemistry 113A. Introduction to surfaces and interfaces of engineering materials, particularly catalytic surface and thin films for solid-state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of crystals and their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C116. Letter grading. Mr. Hicks, Mr. Lu (Sp)

217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, convection, and electrode kinetics, along with applications to electrochemistry, fuel cell design, and modern battery technology. Letter grading. Mr. Nobe (Not offered 2012-13)

C218. Multimedia Environmental Assessment. (4) Lecture, four hours; discussion, one hour; prepara- tion, two hours; outside study, five hours. Recommended requisites: courses 101C, 102B. Pollutant sources, estimation of source releases, waste minimization, transport and fate of chemical pollutants in environment, intermedia transfers of pollutants, multimedia modeling of chemical partitioning in environment, exposure assessment and fundamentals of risk assessment, risk reduction strategies. Concurrently scheduled with course C118. Letter grading. Mr. Cohen (W)


220. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Advanced treatment of mass transfer with applications to industrial separation processes, gas cleaning, pulmonary bioengineering, controlled release systems, and reactor design; molecular and constitutive theories of diffusion, interfacial transport, membrane transport, convective mass transfer, concentration boundary layers, turbulent transport. Letter grading. Mr. Cohen (F)

C221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology. Gas permeation separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Techniques for design of selective membranes and models of membrane transport (flux and selectivity). Examples provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C121. Letter grading. Mr. Cohen (Not offered 2012-13)


Mr. Manousiouthakis (Not offered 2012-13)


Mr. Manousiouthakis (Not offered 2012-13)

223. Design for Environment. (4) Lecture, four hours; outside study, eight hours. Limited to graduate chemical engineering, materials science and engi- neering, or Master of Engineering program students. Design of products for meeting environmental objec- tives; lifecycle inventories; lifecycle impact assessment; design for energy efficiency; design for waste minimization, computer-aided design tools, materials selection methods. Letter grading.

C224. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 222B. Introduction to design and synthesis of biomaterials for regenerative medicine, in vitro cell culture, and drug deliv- ery. Biological principles of cellular microenvironment and design of extracellular matrix analogs using bio- logical and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as thera- peutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently sched- uled with course C124. Letter grading. (Not offered 2012-13)

CM225. Bioseparations and Bioprocess Engi- neering. (4) (Same as Bioengineering M225.) Lecture, four hours; discussion, one hour; outside study; eight hours. Corequisite: course 101C. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reac- tors. Concurrently scheduled with course C125. Let- ter grading.

Mr. Tang (Sp)

CM227. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM227.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requi- sites: Chemistry 153A, Life Sciences 3, 23L. Engi- neering microorganisms for complex phenotype is combined with synthetic biology and systems bio- production. Production of advanced biofuels involves de- signing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biochemical, protein structure, and biological regula- tions and are aided by tools in bioinformatics, sys- tems biology, and molecular biology. Fundamentals of metabolic biochemistry, protein structure and func- tion, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for en- ergy applications. Concurrently scheduled with course CM127. S/U or letter grading. (Not offered 2012-13)


231. Molecular Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 106 or 110. Analysis and design of molecular-beam sys- tems. Molecular-beam sampling of reactive mixtures in combustion chambers or gas jets. Molecular-beam studies of gas-surface interactions, including energy accommodations and heterogeneous reactions. Applica- tions to air pollution control and to catalysis. Let- ter grading.

Mr. Chon


233. Frontiers in Biotechnology. (2) (Formerly numbered CM233.) Lecture, Life Sciences 3. Integration of science and business in biotechnology. Academic research leading to licens- ing and founding of companies that turn research breakthroughs into marketable products. Invited lect- urers from academia and industry cover emerging areas of biotechnology from combination of science, engineering, and business points of view. S/U or letter grading.

234. Plasma Chemistry and Engineering. (4) Lec- ture, four hours; outside study, eight hours. Designed for graduate chemistry or engineering students. Ap- plication of chemistry, physics, and engineering prin- ciples to design and operation of plasma and ion- beam reactors used in etching, deposition, oxidation, and cleaning of materials. Examination of atomic, molecular, and cluster phenomena in plasma and ion-beam processing of semiconductors, etc. Letter grading.

Ms. Chang, Mr. Hicks

C235. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 107. Introduction to advanced process control. Topics include (1) Lyapu- nov stability for autonomous nonlinear systems including converse theorems, (2) input to state stability, interconnected systems, and small gain theorems, (3) design of nonlinear and robust controllers for vari- ous classes of nonlinear systems, (4) model predic- tive control of linear and nonlinear systems, (5) ad- vanced methods for tuning of controllers and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course C135. Letter grading. Mr. Christofides (Sp)

236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 210, C216. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic de- vices. Topics include reactor design, transport phe- nomena and surface chemical kinetics, structure and composition of deposited films, and relationship between process conditions and film properties. Let- ter grading. Mr. Hicks

C237. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Requi- site: course 101C. Technology of particle/gas sys- tems with applications to gas cleaning, commercial production of fine particles, and catalysis. Particle transport and deposition, optical properties, experi- mental methods, dynamics and control of particulate for- mation processes. Concurrently scheduled with course C140. Letter grading. (Not offered 2012-13)

CM245. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM245.) Lecture, four hours; discussion, one hour; outside study, eight hours. Selected topics in molecular biology that form the foundation of biotechnology and biotechnology industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineer- ing, DNA-based diagnostic assays, expression of antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently sched- uled with course CM145. Letter grading. Mr. Liao, Mr. Tang (F)

246. Systems Biology: Intracellular Network Identifica- tion and Analysis. (4) Lecture, four hours; outside study, eight hours. Requisites: course CM245, Life Sciences 1, 2, 3, 4, 5, 23A, 31B, 32A, 33B. Systems approach to intracellular network identification and analysis. Transcriptional regulatory
networks, protein networks, and metabolic networks. Data from genome sequencing, large-scale expression analysis, and other high-throughput techniques provide bases for systems identification and analysis. Discussion of gene-metabolic network synthesis. Letter grading.

Mr. Liao

250. Computer-Aided Chemical Process Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 108B. Application of optimization methods in chemical process design; computer aids in process engineering; process modeling; systematic flowchart invention; process synthesis; design and operation of large-scale chemical processing systems. Letter grading. Mr. Manousiouthakis


Mr. Cohen

270. Principles of Reaction and Transport Phenomena. (4) Lecture, four hours; laboratory, eight hours. Fundamentals in transport phenomena, chemical reaction kinetics and thermodynamics at molecular level. Topics include Boltzmann equation, microscopic chemical kinetics, transition state theory, and statistical analysis of engineering applications related to state-of-art research areas in chemical engineering. Letter grading. Ms. Chang

270R. Advanced Research in Semiconductor Manufacturing. (6) Laboratory, nine hours; outside study, nine hours. Required of all graduate chemical engineering students in M.S. semiconductor manufacturing option. Supervised research in processing semiconductor materials and devices. Letter grading.

M280A. Linear Dynamic Systems. (4) Same as Electrical Engineering M240A and Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvectors and eigenvalues, singular values, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Connections with transfer function techniques. Letter grading.


283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M280A, M282A. Designed for graduate students. Introduction to advanced dynamical analysis and controller synthesis methods for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Banach and Hilbert spaces, semi-group theory, convergence theory in function space, (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition), (3) nonlinear and robust control of semilinear hyperbolic and parabolic partial differential equations (PDEs), (4) applications to transport-reaction processes. Letter grading.

Mr. Christofides


Mr. Manousiouthakis

290. Special Topics. (2 to 4) Seminar, four hours. Requisites for each offering announced in advance by department. Advanced and current study of one or more aspects of chemical engineering, such as chemical process dynamics and control, fuel cells and batteries, membrane transport, advanced chemical engineering analysis, polymers, optimization in chemical process design. May be repeated for credit with topic change. Letter grading.

M297. Seminar: Systems, Dynamics, and Control Topics. (2) Same as Electrical Engineering M248S or Mechanical and Aerospace Engineering M299A.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of current research areas by leading academic researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

298A-298Z. Research Seminars. (2 to 4) Seminar, to be arranged. Requisites for each offering announced in advance by department. Lectures, discussions, student presentations, and projects in areas of current interest. May be repeated for credit. S/U grading. (F,W,Sp)

299. Departmental Seminar. (2) Seminar, two hours. Limited to graduate chemical engineering students. Seminars by leading academic and industrial chemical engineers on development or application of recent technological advances in discipline. May be repeated for credit. S/U grading. (F,W,Sp)

375. Teaching Apprentice Pracitcum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading. (F,W,Sp)

496A. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, four hours; one-day intensive training at beginning of Fall Quarter. Limited to graduate chemical engineering students. Required of all new teaching assistants. Special seminar on communicating chemical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of grading, advising, and rapport with students. S/U grading.

495B. Teaching with Technology for Teaching Assistants. (2) Seminar, two hours; outside study, four hours. One-day intensive training at beginning of Fall Quarter. Limited to graduate chemical engineering students. Designed for teaching assistants interested in learning more about effective use of technology and ways to incorporate that technology into their classrooms for benefit of student learning. S/U grading.

496. Directed Individual or Tutorial Studies. (2 to 8) Tutorial, to be arranged. Limited to graduate chemical engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate chemical engineering students in M.S. semiconductor manufacturing option. Reading and preparation for M.S. comprehensive examination. S/U grading.
Civil and Environmental Engineering

The civil and environmental engineering programs at UCLA include structural engineering, geotechnical engineering, earthquake engineering, hydrology and water resources engineering, and environmental engineering.

The civil engineering curriculum leads to a B.S. in Civil Engineering, a broad-based education in environmental engineering, geotechnical engineering, hydrology and water resources engineering, and structural engineering and mechanics. This program is an excellent foundation for entry into professional practice in civil engineering or for more advanced study. The department also offers the undergraduate Environmental Engineering minor.

At the graduate level, M.S. and Ph.D. degree programs are offered in the areas of civil engineering materials, environmental engineering, geotechnical engineering, hydrology and water resources engineering, and structures (including structural/earthquake engineering and structural mechanics). In these areas, research is being done on a variety of problems ranging from basic physics and mechanics problems to critical problems in earthquake engineering and in the development of new technologies for pollution control and water distribution and treatment.

Department Mission

The Civil and Environmental Engineering Department seeks to exploit its subfield teaching and research strengths as well as to engage in multidisciplinary collaboration. This occurs within the context of a central guiding theme: engineering sustainable infrastructure for the future. Under this theme the department is educating future engineering leaders, most of whom will work in multidisciplinary environments and confront a host of twenty-first-century challenges. With an infrastructure-based vision motivating its teaching and research enterprise, the department conceptualizes and orient its activity toward broadening and deepening fundamental knowledge of the interrelationships among the built environment, natural systems, and human agency.

Undergraduate Program Objectives

The civil engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The objectives of the civil engineering curriculum at UCLA are to (1) provide graduates with a solid foundation in basic mathematics, science, and humanities, as well as fundamental knowledge of relevant engineering principles, (2) provide students with the capability for critical thinking, engineering reasoning, problem solving, experimentation, and teamwork, (3) prepare graduates for advanced study and/or professional employment within a wide array of industries or governmental agencies, (4) produce graduates who understand ethical issues associated with their profession and who are able to apply their acquired knowledge and skills to the betterment of society, and (5) foster in students a respect for the educational process that is manifest by a lifelong pursuit of learning.

Undergraduate Study

The Civil Engineering major is a designated capstone major. In each of the major field design courses, students work individually and in groups to complete design projects. To do so, they draw on their prior coursework, research the needed materials and possible approaches to creating their device or system, and come up with creative solutions. This process enables them to integrate many of the principles they have learned previously and apply them to real systems. In completing their projects, students are also expected to demonstrate effective oral and written communication skills, as well as their ability to work productively with others as part of a team.

Civil Engineering B.S. Capstone Major

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 1, 15; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1), 4AL.

The Major

Required: Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A, Civil and Environmental Engineering 101, 103, 108, 110, 120, 135A, 150, 153, Materials Science and Engineering 104, Mechanical and Aerospace Engineering 103, 182A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and at least nine major field elective courses (36 units) that must include the required courses in two of the following tracks and at least two laboratory courses, one of which must be from one of the two...
Environmental Engineering Minor

The Environmental Engineering minor is designed for students who wish to augment their major program of study with courses addressing issues central to the application of environmental engineering to important environmental problems facing modern society in developed and developing countries. The minor provides students with a greater depth of experience and understanding of the role that environmental engineering can play in dealing with environmental issues.

To enter the minor, students must be in good academic standing (2.0 grade-point average or better) and file a petition in the Office of Academic and Student Affairs, 6426 Boelter Hall.

Required Lower Division Course (5 units):
Mathematics 3C or 32A.

Required Upper Division Courses (24 units minimum): Civil and Environmental Engineering 153 and five courses from 151, 154, 155, 156A, M166, Chemical Engineering C118, Environmental Health Sciences C125, C164.

A minimum of 20 units applied toward the minor requirements must be in addition to units applied toward major requirements or another minor.

No more than two upper division courses may be applied toward both this minor and a major or minor in another department or program, and at least 16 units applied toward the minor must be taken in residence at UCLA. Transfer credit for any of the above is subject to departmental approval; consult the undergraduate counselors before enrolling in any courses for the minor.

Each minor course must be taken for a letter grade, and students must have a minimum grade of C (2.0) in each and an overall grade-point average of 2.0 or better. Successful completion of the minor is indicated on the transcript and diploma.

Graduate Study

For information on graduate admission, see Graduate Programs, page 23.

The following introductory information is based on the 2012-13 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmmqintro.htm. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

The Department of Civil and Environmental Engineering offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Civil Engineering.

Civil Engineering M.S.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses are required, a majority of which must be in the Civil and Environmental Engineering Department. At least five of the courses must be at the 200 level. In the thesis plan, seven of the nine must be formal 100- or 200-series courses. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, 500-series courses may not be applied toward the nine-course requirement. A minimum 3.0 grade-point average is required in all coursework.

Each major field has a set of required preparatory courses which are normally completed during undergraduate studies. Equivalent courses taken at other institutions can satisfy the preparatory course requirements. The preparatory courses cannot be used to satisfy course requirements for the M.S. degree; courses must be selected in accordance with the lists of required graduate and elective courses for each major field.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

The M.S. degree offers four fields of specialization that have specific course requirements.

Civil Engineering Materials

Required Preparatory Courses. General chemistry and physics with laboratory exercises, multivariate calculus, linear algebra, and differential equations, introductory thermodynamics. Other undergraduate preparation could include Civil and Environmental Engineering C104, 120, 121, 135A, 140L, 142, and Materials Science and Engineering 104.

Required Graduate Courses. Two courses must be selected from Civil and Environmental Engineering C204, 226, 253, 258A, 261B, M262A, 263A, 266, 267.

Environmental Engineering

Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 153; Mathematics 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.

Required Graduate Courses. Civil and Environmental Engineering 250A through 250D.

Major Elective Courses. Minimum of three courses must be selected from Civil and Environmental Engineering 251A through 251D, 252, 253, 260.


Structural/Earthquake Engineering

Required Preparatory Courses. Civil and Environmental Engineering 135A, 135B, and 141 (or 142).

Required Graduate Courses. Civil and Environmental Engineering 235A, 246, and at least three courses from 235B, 241, 243A, 245, 247.


Structural Mechanics

Required Preparatory Courses. Civil and Environmental Engineering 130, 135A, 135B.

Required Graduate Courses. Civil and Environmental Engineering 232, 235A, 235B, 236, M237A.


Comprehensive Examination Plan

In addition to the course requirements, under this plan there is a comprehensive written examination covering the subject matter contained in the program of study. The examination is administered by a comprehensive examination committee, which may conduct an oral examination in addition to the written examination. In case of failure, the examination may be repeated once with the consent of the graduate adviser.

Thesis Plan

In addition to the course requirements, under this plan students are required to write a thesis on a research topic in civil and environmental engineering supervised by the thesis adviser. An M.S. thesis committee reviews and approves the thesis. No oral examination is required.

Civil Engineering Ph.D.

Major Fields or Subdisciplines

Civil engineering materials, environmental engineering, geotechnical engineering, hydrology and water resources engineering, structural/earthquake engineering, and structural mechanics.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may theoretically substitute coursework by examinations. However, students normally take courses to acquire the knowledge needed for the required written and oral preliminary examinations. The basic program of study for the Ph.D. degree is built around one major field and two minor fields. The major field has a scope corresponding to a body of knowledge contained in a detailed Ph.D. field syllabus available on request from the department office. Each minor field normally embraces a body of knowledge equivalent to three courses from the selected field, at least two of which are graduate courses. Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor fields are selected to support the
major field and are usually subsets of other major fields.

**Written and Oral Qualifying Examinations**

After mastering the body of knowledge defined in the major field, students take a written preliminary examination. When the examination is passed and all coursework is completed, students take an oral preliminary examination that encompasses the major and minor fields. Both preliminary examinations should be completed within the first two years of full-time enrollment in the Ph.D. program. Students may not take an examination more than twice.

After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination is at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

**Note:** Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, must be inside members who hold full-time faculty appointments in the department. The outside member must be a UCLA faculty member in another department.

**Fields of Study**

**Civil Engineering Materials**

Ongoing research is focused on inorganic, random porous materials and incorporates expertise at the interface of chemistry and materials science to develop the next generation of sustainable construction materials. The work incorporates aspects of first principles and continuum scale simulations and integrated experiments, ranging from nano- to macro scales. Special efforts are devoted toward developing low-clinker factor cements and concretes, reducing the carbon footprint of construction materials, and increasing the service life of civil engineering infrastructure.

**Environmental Engineering**

Research in environmental engineering focuses on the understanding and management of physical, chemical, and biological processes in the environment and in engineering systems. Areas of research include process development for water and wastewater treatment systems and the investigation of the fate and transport of contaminants in the environment.

**Geotechnical Engineering**

Research in geotechnical engineering focuses on understanding and advancing the state of knowledge on the effects that soils and soil deposits have on the performance, stability, and safety of civil engineering structures. Areas of research include laboratory investigations of soil behavior under static and dynamic loads, constitutive modeling of soil behavior, behavior of structural foundations under static and dynamic loads, soil improvement techniques, response of soil deposits and earth structures to earthquake loads, and the investigation of geotechnical aspects of environmental engineering.

**Hydrology and Water Resources Engineering**

Ongoing research in hydrology and water resources deals with surface and groundwater processes, hydrometeorology and hydroclimatology, watershed response to disturbance, remote sensing, data assimilation, hydrologic modeling and parameter estimation, multiobjective resources planning and management, numerical modeling of solute transport in groundwater, and optimization of conjunctive use of surface water and groundwater.

**Structures (Structural Mechanics and Earthquake Engineering)**

Research in structural mechanics is directed toward improving the ability of engineers to understand and interpret structural behavior through experiments and computer analyses. Areas of special interest include computer analysis using finite-element techniques, computational mechanics, structural dynamics, nonlinear behavior, plasticity, micromechanics of composites, damage and fracture mechanics, structural optimization, probabilistic static and dynamic analysis of structures, and experimental stress analysis.

Designing structural systems capable of surviving major earthquakes is the goal of experimental studies on the strength of full-scale reinforced concrete structures, computer analysis of soils/structural systems, design of earthquake resistant masonry, and design of seismic-resistant buildings and bridges.

Teaching and research areas in structural/earthquake engineering involve assessing the performance of new and existing structures subjected to earthquake ground motions. Specific interests include assessing the behavior of reinforced concrete buildings and bridges, as well as structural steel, masonry, and timber structures. Integration of analytical studies with laboratory and field experiments is emphasized to assist in the development of robust analysis and design tools, as well as design recommendations. Reliability-based design and
performance assessment methodologies are also an important field of study.

Facilities
The Civil and Environmental Engineering Department has a number of laboratories to support its teaching and research:

Instructional Laboratories
Advanced Soil Mechanics Laboratory
The Advanced Soil Mechanics Laboratory is used for presenting and performing advanced triaxial, simple shear, and consolidation soil tests. It is also used for demonstration of cyclic soil testing techniques and advanced data acquisition and processing.

Environmental Engineering Laboratories
The Environmental Engineering Laboratories are used for the study of basic laboratory techniques for characterizing water and wastewaters. Selected experiments include measurement of biochemical oxygen demand, suspended solids, dissolved oxygen, sediment distributions, and other parameters used in water quality control.

Experimental Fracture Mechanics Laboratory
The Experimental Fracture Mechanics Laboratory is used for preparing and testing specimens using modern dynamic testing machines to develop an understanding of fracture mechanics and to become familiar with experimental techniques available to study crack tip stress fields, strain energy release rate, surface flaws, and crack growth in laboratory samples.

Hydrology Laboratory
The Hydrology Laboratory is used for studying basic surface water processes and characterizing a range of geochemical parameters. Basic experiments include measurements of suspended solids, turbidity, dissolved oxygen, sediment distributions, and other basic water quality constituents. The laboratory also includes an extensive suite of equipment for measuring surface water processes in situ, including precipitation, stage height, discharge, channel geomorphology, and other physical parameters.

Mechanical Vibrations Laboratory
The Mechanical Vibrations Laboratory is used for conducting free and forced vibration and earthquake response experiments on small model structures such as a three-story building, a portal frame, and a water intake/outlet tower for a reservoir. Two electromagnetic exciters, each with a 30-pound dynamic force rating, are available for generating steady state forced vibrations. A number of accelerometers, LVDTs (displacement transducers), and potentiometers are available for measuring the motions of the structure. A laboratory view-based computer-controlled dynamic data acquisition system, an oscilloscope, and a spectrum analyzer are used to visualize and record the motion of the model structures.

Two small electromagnetic and servohydraulic shaking tables (1.5 ft. x 1.5 ft. and 2 ft. x 4 ft.) are available to simulate the dynamic response of structures to base excitation such as earthquake ground motions.

Reinforced Concrete Laboratory
The Reinforced Concrete Laboratory is available for students to conduct monotonic and cyclic loading to verify analysis and design methods for moderate-scale reinforced concrete slabs, beams, columns, and joints, which are tested to failure.

Soil Mechanics Laboratory
The Soil Mechanics Laboratory is used for performing experiments to establish data required for soil classification, soil compaction, shear strength of soils, soil settlement, and consolidation characteristics of soils.

Structural Design and Testing Laboratory
The Structural Design and Testing Laboratory is used for the design/optimization, construction, instrumentation, and testing of small-scale structural models to compare theoretical and observed behavior. Projects provide integrated design/laboratory experience involving synthesis of structural systems and procedures for measuring and analyzing response under load.

Research Laboratories
Building Earthquake Instrumentation Network
The Building Earthquake Instrumentation Network consists of more than 100 earthquake strong motion instruments in three campus buildings to measure the response of actual buildings during earthquakes. When combined with over 50 instruments placed in four California Division of Mines and Geology Strong Motion Program, represents the most detailed building instrumentation network in the world. The goal of the research conducted using the response of these buildings is to improve computer modeling methods and the ability of structural engineers to predict the performance of buildings during earthquakes.

Environmental Engineering Laboratories
The Environmental Engineering Laboratories are used for conducting water and wastewater analysis, including instrumental techniques such as GC, GC/MS, HPLC, TOC, IC, and particle counting instruments. A wide range of wet chemical analysis can be made in this facility with 6,000 square feet of laboratory space and an accompanying 4,000-square-foot rooftop facility where large pilot scale experiments can be conducted. Additionally, electron microscopy is available in another laboratory.

Recently studies have been conducted on oxygen transfer, storm water toxicity, transport of pollutants in soil, membrane fouling, removal from drinking water, and computer simulation of a variety of environmental processes.

Experimental Mechanics Laboratory
The Experimental Mechanics Laboratory supports two major activities: the Optical Metrology Laboratory and the Experimental Fracture Mechanics Laboratory.

In the Optical Metrology Laboratory, tools of modern optics are applied to engineering problems. Such techniques as holography, speckle-interferometry, Moiré analysis, and fluorescence-photo mechanics are used for obtaining displacement, stress, strain, or velocity fields in either solids or liquids. Recently, real-time video digital processors have been combined with these modern optical technical techniques, allowing direct interfacing with computer-based systems such as computer-aided testing or robotic manufacturing.

The Experimental Fracture Mechanics Laboratory is currently involved in computer-aided testing (CAT) of the fatigue fracture mechanics of ductile material. An online dedicated computer controls the experiment as well as records and manipulates data.

Large-Scale Structure Test Facility
The Large-Scale Structure Test Facility allows investigation of the behavior of large-scale structural components and systems subjected to gravity and earthquake loadings. The facility consists of a high-bay area with a 20 ft. x 50 ft. strong floor with anchor points at 3 ft. on center. Actuators with servohydraulic controllers are used to apply monotonic or cyclic loads. The area is ser-
vided by two cranes. The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings.

Associated with the laboratory is an electro-hydraulic universal testing machine with force capacity of 100 tons. The machine is used mainly to apply tensile and compressive loads to specimens so that the properties of the materials from which the specimens are made can be determined. It can also be used in fatigue-testing of small components.

Soil Mechanics Laboratory

The Soil Mechanics Laboratory is used for standard experiments and advanced research in geotechnical engineering, with equipment for static and dynamic triaxial and simple shear testing. Modern computer-controlled servo-hydraulic closed-loop system supports triaxial and simple shear devices. The system is connected to state-of-the-art data acquisition equipment. The laboratory also includes special simple shear apparatuses for small-strain static and cyclic testing and for one-dimensional or two-dimensional cyclic loading across a wide range of frequencies. A humidity room is available for storing soil samples.

Faculty Areas of Thesis Guidance

Professors

Jiun-Shyan (J-S) Chen, Ph.D. (Northwestern, 1969)

Physical and chemical environmental processes, colloidal and interfacial phenomena, environmental membrane separations, bio-adhesion and bio-fouling


Damage mechanics, mechanics of composite materials, computational plasticity, micromechanics, concrete modeling and durability, computational mechanics

Steven A. Mangulis, Ph.D. (MIT, 2002)

Surface hydrology, hydrometeorology, remote sensing, data assimilation

Michael K. Stenstrom, Ph.D. (Clemson, 1976)

Process development and control for water and wastewater treatment plants

Jonathan P. Stenstrom, Ph.D. (UC Berkeley, 1996)

Geotechnical engineering, earthquake engineering

Keith D. Stolzenbach, Ph.D. (MIT, 1971)

Environmental fluid mechanics, fate and transport of pollutants, dynamics of particles

Mladen Vuctic, Ph.D. (Rensselaer, 1986)

Geotechnical engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties

John W. Wallace, Ph.D. (UC Berkeley, 1988)

Earthquake engineering, design methodologies, seismic evaluation of existing buildings, large-scale testing laboratory and field testing

William W-G. Yeh, Ph.D. (Stanford, 1967)

Hydrology and optimization of water resources systems

Professors Emeriti

Stanley B. Dong, Ph.D. (UC Berkeley, 1962)

Structural mechanics, structural dynamics, finite element methods, numerical methods and mechanics of composite materials

Lewist P. Felton, Ph.D. (Carnegie Institute of Technology, 1964)

Structural analysis, structural mechanics, automated optimum design structure, including reliability-based design

Michael E. Fournier, Ph.D. (Caltech, 1963)

Experimental mechanics, emphasis on application of modern optical techniques

Gary C. Hart, Ph.D. (Stanford, 1968)

Structural engineering analysis and design of buildings for earthquake and wind loads, structural dynamics, and uncertainty and risk analysis of structures

Poul V. Lade, Ph.D. (UC Berkeley, 1972)

Soil mechanics, stress-strain and strength characteristics of soils, deformation and stability analyses of foundation engineering problems

Chung Yen Liu, Ph.D. (Caltech, 1962)

Fluid mechanics, environmental, numerical

Richard L. Perrine, Ph.D. (Stanford, 1953)

Resource and environmental problems—chemical, petroleum, or hydrological, physics of flow through porous media, transport phenomena, kinetics

Moshe F. Rubinstein, Ph.D. (UCLA, 1961)

Systems analysis and design, problem-solving and decision-making models

Lucien A. Schmit, Jr., M.S. (MIT, 1950)

Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components

Lawrence G. Seina, Ph.D. (UC Berkeley, 1967)

Reinforced concrete, earthquake engineering

Associate Professors

Scott J. Brandenberg, Ph.D. (UC Davis, 2005)

Geotechnical earthquake engineering, soil-structure interaction, liquefaction, data acquisition and processing, numerical analysis

Jennifer A. Jay, Ph.D. (MIT, 1999)

Aquatic chemistry, environmental microbiology

Ertugri Tacioglu, Ph.D. (Illinois, Urbana-Champaign, 1996)

Computational structural and solid mechanics and constitutive modeling of materials

Jian Zhang, Ph.D. (UC Berkeley, 2002)

Earthquake engineering, structural dynamics and mechanics, seismic protective devices and strategies, soil-structure interaction, and bridge engineering

Assistant Professors

Shaily Mahendra, Ph.D. (UC Berkeley, 2007)

Environmental microbiology, biodegradation of groundwater contaminants, microbial-nanomaterial interactions, nanotoxicology, applications of molecular biological and isotopic tools in environmental engineering

Gaurav Sant, Ph.D. (Purdue, 2009)

Cementitious materials and porous media with focus on chemistry-microstructure-property relationships, geochemical modeling, shrinkage and cracks, durability of interfaces, durability prediction and extension, and carbon footprint minimization of construction materials

Senior Lecturer

Christopher Tu, Ph.D. (UC Davis, 1975)

Groundwater movement and surface water hydrology

Adjunct Professors

Thomas Sabol, Ph.D. (UCLA, 1985)

Seismic performance and structural design issues for steel and concrete seismic force resisting systems; application of probabilistic methods to earthquake damage quantification

Ne-Zheng Sun, Ph.D. (Shandong U., 1965)

Mathematical modeling of groundwater flow and contaminant transport, water resources management, numerical analysis and optimization

Adjunct Associate Professors


Surface hydrology, watershed characterization (physical and chemical), remote sensing, hydrologic and land surface modeling, and parameter estimation

Donald R. Kendall, Ph.D. (UCLA, 1989)

Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes

Issam Najmi, Ph.D. (Illinois, Urbana-Champaign, 1990)

Water chemistry, physical and chemical processes in drinking water treatment

Daniel E. Pradell, Ph.D. (U. Tokyo, 1987)

Soil mechanics and foundation engineering

Lower Division Courses

1. Introduction to Civil Engineering. (2) Lecture, two hours; outside study, four hours. Introduction to scope of civil engineering profession, including earthquake, environmental, geotechnical, structural, transportation, and water resources engineering. P/NP grading.

Mr. Chen (F)

15. Introduction to Computing for Civil Engineers. (2) Lecture, two hours; laboratory, two hours; outside study, two hours. Introduction to computer programming using MATLAB. Selected topics in programing, with emphasis on numerical techniques and methodology as applied to civil engineering programs. Letter grading.

Mr. Chen, Mr. Ju (F,W)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

58SL. Climate Change, Water Quality, and Ecosystem Functioning. (5) Lecture, four hours; service learning, two hours; outside study, nine hours. Science related to climate change, water quality, and ecosystem health. Topics include carbon and nutrient cycling, hydrologic cycle, ecosystem structure and services, biodiversity, basic aquatic chemistry, and impacts of climate change, ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading.

Ms. Jay (Sp)

85. Professional Practice Issues in Structural Engineering. (2) Seminar, two hours; outside study, four hours. Introduction to issues of professional practice in structural engineering. Content and organization of model building codes and material-specific reference standards. Interpretation of architectural and structural design drawings and specifications. Material-independent structural calculations such as tributary area, multistory columns, loads, and estimation of simple seismic and wind loads. P/NP grading.

Mr. Wallace

97. Variable Topics in Civil and Environmental Engineering. (2 to 4) Seminar, two hours. Current topics and research methods in civil and environmental engineering. May be repeated for credit. Letter grading.

11. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course).

Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.
Upper Division Courses

101. Statics and Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 31A, 31B, Physics 1A. Newtonian mechanics, vector representation, and resultant forces and moments. Free-body diagrams and equilibrium in two- and three-dimensional systems. Linear and angular momentum and impulse. Multi- particle systems. Kinematics and kinetics of rigid bodies in two- and three-dimensional motions. Letter grading. Mr. Ju (F)

103. Applied Numerical Computing and Modeling in Civil and Environmental Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Six hours; discussion, two hours; outside study, six hours. Requisite: course 108. Soil as foundation structures and as material of construction. Soil formation, classification, physical and mechanical properties, soil compaction, earth pressures, consolidation, and shear strength. Letter grading. Mr. Vucetic (F)

121. Design of Foundations and Earth Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Design, analysis and design of earth dams, including seepage, piping, and slope stability analyses. Case history studies involving landslides, settlement, and expansive soil problems. Design of slopes and earth retaining structures. Letter grading. Mr. Stewart (W)


128L. Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, eight hours; outside study, three hours. Requisite or corequisite: course 120. Laboratory experiments to be performed by students to obtain soil parameters required for assigned design problems. Soil mechanics, classification, Atterberg limits, specific gravity, compaction, index, consolidation, shear strength determination, analysis problems, laboratory report writing. Letter grading. Mr. Stewart (F)

129. Engineering Geometrics. (4) Lecture, two hours; recitation, two hours; fieldwork, four hours; outside study, four hours. Collection, processing, and analysis of geospatial data. Ellipsoid and geodetic mod- els of shape of Earth, Sea level, heights, geop- tential surfaces. Elements and usage of topographic data and maps. Advanced global positioning systems (GPS) for high-precision mapping. Advanced laser- based light detection and range (LIDAR) mapping. Quantitative terrain analysis and change detection. Hydrogeometrics: seafloor mapping. Letter grading. Mr. Stewart (W)

130. Elementary Structural Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requirement for course 135A. Analysis of stress and strain, phenomenological material behavior, extension, bending, and transverse shear stresses in beams with general cross-sections, shear center, deflection of beams, torsion of beams, warping, column instability and failure. Letter grading. Mr. Taciglugi (W)


135A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 15, 103, 108. Introduction to structural analysis; classification of structural elements; analysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of indeterminate structures using force method; introduction to displacement method and energy concepts. Letter grading. Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; matrix displacement method; analysis concepts based on theorem of virtual work; moment distribution. Letter grading. Mr. Ju (W)

M135C. Introduction to Finite Element Methods. (4) (Same as Mechanical and Aerospace Engineer- ing M168.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 130 or Mechanical and Aerospace Engineering 156A or 166A. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties, isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; pre-processing and postpro- cessing techniques; term projects with computers. Letter grading. Mr. Ju (F)

135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 15, 135A. Limited- ed enrollment. Computer-aided optimum design, con- struction, instrumentation, and test of small-scale model structure. Use of computer-based data acquisi- tion and interpretation systems for comparison of experimental and theoretically predicted behavior. Letter grading. Mr. Stewart (F)

137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics. Course foundation for civil engineering. Free- free, forced vibration, and earthquake response spectra analysis for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams, shafts, and columns. Letter grading. Mr. Ju (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Cali- bration of instrumentation for dynamic measure- ments. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic similitude. Letter grading. Mr. Ju (Not offered 2012-13)

142L. Reinforced Concrete Structural Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisites: courses 135B, 142. Limited enrollment. Design considerations used for reinforcing concrete beams, columns, slabs, and joints evaluated using analysis and experiments. Links between theory, building codes, and experimental results. Students demonstrate accuracies and limitations of calculation procedures used in design of reinforced concrete structures. Development of skills for written and oral presentations. Letter grading. Mr. Wallace (Not offered 2012-13)

143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 135A, 142. Prestressing and post-tensioning techniques. Properties of concrete and prestressing steels. Design considerations and anchorage/bonding of cables. Prestressed concrete analysis by superposition and strength methods, draping of cables, deflection and stiffness, indeterminate structures, limitation of prestressing. Letter grading. Mr. Wallace (Sp)


150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 15, Mechanical and Aerospace Engineering 103. Study of hydrologic cycle and relevant atmospheric processes, water and energy balance, radiation, precipitation formation, infiltration, evaporation, vegetation transpiration, groundwater flow, storm runoff, and surface processes. Letter grading. Mr. Margulis (F)

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite courses: course 150. Text: Introduction to Water Resources Engineering, 1st ed., by Haynes and Day. Recommended: courses 103, 110. Principles of hydrodynamics, flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydraulic power systems, system analysis, and design applied to water resources engineering. Letter grading. Mr. Margulis (W)

153. Introduction to Environmental Engineering Science. (4) Lecture, four hours; discussion, one hour (when scheduled); outside study, seven hours. Recommended requisite: Mechanical and Aerospace Engineering 103. Water, air, and soil pollution: sources, transformations, effects, and processes for removal of contaminants. Water quality, water and wastewater treatment, waste disposal, air pollution, global environmental problems. Field trip. Letter grading. Mr. Stolzenbach (F)

154. Chemical Fate and Transport in Aquatic Environments. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Fundamental physical, chemical, and biologic processes governing movement and fate of chemicals in surface waters and groundwater. Topics include physical transport in various aquatic environments, air-water exchange, acid-base equilibria, oxidation-reduction chemistry, chemical sorption, biodegradation, and plant uptake. Watershed modeling and quantifying problems solved considering both reaction and transport of chemicals in environment. Letter grading. Mr. Hoek (F)

156A. Environmental Chemistry Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: course 153 may be taken concurrently. Text: Chemical 20A, 20B. Basic laboratory techniques in analytical chemistry related to water and wastewater quality. Field trip required. Laboratory experiments include gravimetric analysis, titrimetry spectrophotometry, redox systems, pH and electrical conductivity. Concepts to be applied to analysis of "real" water samples in course 156B. Letter grading. Mr. Stenstrom (FSp)

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Laboratory, six hours; discussion, two hours; outside study, four hours. Requisites: Chemistry 20A, 20B. Characterization and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chloride residual, that are used in unit operation experiments that include reactor dynamics, aeration, gas stripping, coagulation/precipitation, and membrane separation. Letter grading. Ms. Jay (Sp)

157A. Hydrologic Modeling. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 150, 151. Introduction to hydrologic modeling. Corequisite: course 155. (1) open-channel flow, including one-dimensional steady flow, unsteady flow, and sediment transport, (2) pipe flow and water distribution systems, (3) rainfall-runoff modeling, and (4) groundwater flow modeling, with a focus on use of industry and/or research standard models with locally relevant applications. Letter grading. Mr. Stenstrom (W)

157B. Design of Water Treatment Plants. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; outside study, four hours. Requisite: course 155. Water quality standards and regulations, overview of water treatment plants, design of unit operations, predesign of water treatment plants, hydraulics of plants, process control, antiscalant estimation. Letter grading. Mr. Stenstrom (Not offered 2012-13)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Requisite course 155. Process design of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and economics. Letter grading. Mr. Stenstrom (Sp)

157L. Hydrologic Analysis and Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 150 and/or 151. Collection, interpretation and data of quantification of surface water components of hydrologic cycle, including precipitation, evaporation, infiltration, and runoff. Use of hydrologic variables and parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Field trip required. Letter grading. Mr. Margulis (Sp)

157M. Hydrology of Mountain Watersheds. (4) Lecture, one hour; fieldwork, four hours; laboratory, three hours; outside study, four hours; one field trip. Requisites: courses 150 or 151. Field- and laboratory-based course with focus on study of hydrologic and geophysical processes in snow-dominated and montane regions. Emphasis on measuring and quantifying snowpack properties, snowmelt, discharge, evaporation, infiltration, soil properties, and local meteorology, as well as investigation geophysical properties of surface and groundwater systems. Exploration of rating curves, stream classification, and flooding potential. Extended field trip required. Letter grading. Mr. Margulis (Not offered 2012-13)

163. Introduction to Atmospheric Chemistry and Air Pollution. (4) Lecture, four hours; outside study, eight hours. Requisites: course 153, Chemistry 20A, Mathematics 31A, 31B, Physics 1A, 1B. Description of processes affecting chemical composition of troposphere; air pollutant concentrations/standards, urban and regional ozone, aerosol pollution, formation/deposition of acid precipitation, fate of anthropogenic/toxic/natural organic and inorganic components. Control technologies. Letter grading. Mr. Stolzenbach (Not offered 2012-13)


M166. Environmental Microbiology. (4) Same as Environmental Health Sciences M166.) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Microbial cell and its metabolic capabilities, microbial genetics and its potentials, growth of microbes and kinetics of growth, microbial ecology and diversity, microbiology of wastewater treatment, probing of microbes, advanced topics in environmental microbiology, pathogenesis and infection. Letter grading. Ms. Mahendra (W)

M166L. Environmental Microbiology and Biotechnology Laboratory. (1) (Same as Environmental Health Sciences M166L.) Laboratory, two hours; outside study, two hours. Corequisite: course M166. General laboratory practice within environmental microbiology, sampling of environmental samples, classical and modern molecular techniques for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples, laboratory setups for studying environmental microbiology. Letter grading. Ms. Mahendra (Not offered 2012-13)
Graduate Courses

C204. Structure, Processing, and Properties of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Discussion of aspects of cement and concrete materials, including manufacture of cement and production of concrete. Aspects of cement composition and basic chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control and acceptance testing. Development and testing of fundamentals for complete understanding of overall response of all civil engineering materials. \[\text{Course: C204} \] Letter grading. Mr. Sant (W)


221. Advanced Foundation Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 121, 220. Stress distribution. Bearing capacity and settlement of shallow foundations, including spread footings. Design of driven pile and drilled shaft foundations under vertical and lateral loading. Construction considerations. Letter grading. Mr. Brandenberg (W)

222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Review of engineering problems involving soil dynamics. Fundamentals of theoretical soil dynamics: response of sliding block-on-plane to cyclic earthquake loads, application of theories of single degree-of-freedom (DOF) system, multiple DOF system and one-dimensional wave propagation. Fundamentals of cyclic soil behavior: stress-strain-pore water pressure behavior, shear modulus and damping, cyclic settlement and concept of volumetric cyclic threshold shear strain. Introduction to modeling of cyclic soil behavior. Letter grading. Mr. Vucetic (W)

223. Slope Stability and Earth Retention Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 121, 220. Basic concepts of stability of earth slopes, including shear strength, design charts, limit equilibrium analysis, staged construction, and rapid drawdown. Theory of earth pressures behind retaining structures, with special application to design of retaining walls, sheet piles, mechanically stabilized earth, soil nails, and anchored and braced excavations. Letter grading. Mr. Brandenberg (W)

224. Advanced Cyclic and Monotonic Soil Behavior. (4) Lecture, four hours; outside study, eight hours. Requisites: course 120. In-depth study of soil behavior under cyclic and monotonic loads. Relationships between stress, strain, pore water pressure, and volume change in range of very small and large strains. Concept of normalized static and cyclic soil behavior. Cyclic degradation and liquefaction of saturated soils. Cyclic settlement of partially saturated and dry soils. Concept of volumetric cyclic threshold shear strain. Factors affecting shear moduli and damping during cyclic loading. Postcyclic behavior under monotonic loads. Critical review of laboratory, field, and modeling testing techniques. Letter grading. Mr. Vucetic (F)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 220, 245 (may be taken concurrently). Analysis of earthquake-induced ground failure, including soil liquefaction. Laboratory studies of cyclic soil behavior under cyclic and monotonic loads. Laboratory methods for soil property evaluation. Letter grading. Mr. Vucetic (F)

226. Geoenvironmental Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental regulations, waste management, geotechnical aspects of solid waste disposal, subsurface barrier walls, and disposal of high water content materials. Letter grading. Mr. Vucetic, Mr. Stewart (Sp)

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of computer modeling of soils using finite element method, and to constitutive modeling based on elasticity and plasticity theories. Solution techniques for linear and non-linear systems of equations. Letter grading. Mr. Vucetic

228L. Advanced Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, eight hours. Requisite: course 221. Topics in laboratory studies involving advanced aspects of soil behavior and their application to design. Test to determine permeability, consolidation, and shear strength. Review of advanced instrumentation and measurement techniques. Letter grading. Mr. Vucetic (W)

M230A. Linear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerrutti. Introduction to boundary integral equation method. Letter grading. Mr. Ju, Mr. Mal (F, Sp)

M230B. Nonlinear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course 230A. Kinematic material and spatial coordinates, deformation gradient tensor, non-linear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stress tensors; Cauchy equations of motion; balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (W)


232. Theory of Plates and Shells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Small and large deformation theories of thin plates; energy methods; free vibrations; membrane theory of shells; axisymmetric deformations of cylindrical and spherical shells, including bending. Letter grading. Mr. Ju, Mr. Mal (F)


244. Advanced Topics in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Limited to graduate engineering students. Current topics in composite materials, computational methods, finite element analysis, structural synthesis, nonlinear mechanics, and structural mechanics in general. Topics may vary from term to term. Letter grading. Mr. Ju (Sp)

235A. Advanced Structural Analysis. (4) Lecture, four hours; outside study, eight hours. Requisite: course 135A. Recommended: course 135B. Review of matrix force and displacement methods of structural analysis; virtual work theorem, virtual forces, and displacements; theorems on stationary value of total and complementary potential energy, minimum total potential energy, Maxwell/Betti theorems, effects of applied forces, interpolation: a finite element analysis. Letter grading. Mr. Ju, Mr. Tairoglo (F)

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, 235A. Direct energy formulation for deformable solids; methods for linear equations; analysis of structural systems with one-dimensional elements; introduction to variational...
244. Structural Loads and Safety for Civil Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 235B. Classification of nonlinear effects; material nonlinearities; conservative, nonconservative behavior; geometric nonlinearities; Lagrangian, Eulerian description of motion; finite element methods in geometrically nonlinear problems; postbuckling behavior of structures; solution of nonlinear equations; incremental, iterative, programming methods. Letter grading. Mr. Ju, Mr. Taciroglu (Sp)


M237A. Dynamics of Structures. (4) (Same as Mechanical and Aerospace Engineering M269A.) Lecture, four hours; outside study, eight hours. Requisite: course 137. Principles of dynamics. Determination of normal modes; frequency equations by differential and integral equation solutions. Transient and steady state response. Emphasis on derivation and solution of governing equations using matrix formulations. Letter grading. Mr. Bendiksen, Mr. Ju (W)


241. Advanced Steel Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 137, 141, 235A. Performance characterization of steel structures for static and earthquake loads. Behavior state analysis and building code provisions for special moment resisting, braced, and eccentric braced frames. Composite steel-concrete structures. Letter grading. Mr. Ju (Sp)


243A. Behavior and Design of Reinforced Concrete Structural Elements. (4) Lecture, four hours; outside study, eight hours. Requisite: course 142. Advanced topics on design of reinforced concrete structures, including stress-strain relationships for plain and confined concrete, moment-curvature analysis of sections, and design for shear. Design of slender and low-rise walls, as well as columns and beam-column joints. Introduction to displacement-based design and applications of strut-and-tie models. Letter grading. Mr. Wallace (F)

243B. Response and Design of Reinforced Concrete Structural Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 243A, 246. Information on response and behavior of reinforced concrete buildings to earthquake ground motions. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, and ductility in design, use of prescriptive versus performance-based design methodologies, and application of elastic and inelastic forces for inelastic and existing construction. Letter grading. Mr. Wallace (W)

250C. Hydrometeorology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A. Introduction to hydrologic processes. Role of hydrology in climate system, precipitation and evaporation processes, atmospheric radiation, exchange of mass, heat, and momentum between soil and vegetation system and overlying atmosphere, flux and transport in turbulent boundary layer, basic remote sensing principles. Letter grading. Mr. Margulis (W)

250D. Water Resources Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 151. Application of mathematical programming techniques to water resources systems. Topics include reservoir management and operation; optimization, sequencing and sizing of water resources projects; and multiobjective planning and conjunctive use of surface water and groundwater. Emphasis on management of water quantity. Letter grading. Mr. Yeh (W)

251A. Rainfall-Runoff Modeling. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 251B. Introduction to hydrologic modeling concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed model formulations, parameter estimation and sensitivity analysis, and application of models for flood forecasting and prediction of streamflows in water resource applications. Letter grading. Mr. Margulis (Not offered 2012-13)

251B. Contaminant Transport in Groundwater. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250B, 250C. Introduction to basic physical concepts of remote sensing as they relate to surface and atmospheric hydrologic processes. Applications include radiative transfer modeling and retrieval of hydrologically relevant parameters such as topography, soil moisture, snow properties, vegetation, and precipitation. Letter grading. Mr. Yeh (Not offered 2012-13)

251C. Remote Sensing with Hydrologic Applications. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic concepts of classical and Bayesian estimation theory for purposes of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models of hydrologic systems. Letter grading. Mr. Margulis (Not offered 2012-13)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; outside study, eight hours. Requisites: course 106A, one or more courses from Economics 1, 2, 11, 100, 101. Economic theory and applications in analysis and management of water and environmental problems; application of price theory to water resource development and environmental planning; benefit-cost analysis with applications to water resources and environmental planning. Letter grading. Mr. Yeh (Sp)


254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture, four hours; outside study, eight hours. Requisites: Chemistry 31A, 31B, Physics 1A, 1B. Equilibrium and kinetic descriptions of chemical behavior of metals and inorganic...
ions in natural fresh/marine surface waters and in wa-
ter treatment. Processes include acid-base chemistry and
and algae, and the role of colloids and semipermeable
membranes in diagenesis, adsorption/desorption, bior-
capsulation, and nutrient regeneration. (W)

256B. Atmospheric Diffusion and Air Pollution. (4) (Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollutants, processes of mixing, and dispersion of air pollutants in different environments. Letter grading. (W)

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Transfer processes in surface water, groundwater, and atmosphere. Emphasis on experiments and modeling of chemical and physical processes in various environmental systems. Letter grading. Mr. Stolzenbach (Not offered 2012-13)

263B. Advanced Topics in Transport at Environ-
mental Interfaces. (4) Lecture, four hours; outside study, eight hours. In-depth treatment of selected topics involving transport phenomena at environmental interfaces between solid, fluid, and gas phases, including aquatic sediments, porous media, and vegetative canopies. Discussion of theoretical models and experimental observations. Application to important environmental engineering problems. Letter grading. Mr. Stolzenbach (Not offered 2012-13)

265A. Mass Transfer in Environmental Systems. (4) Lecture, four hours; computer applications, two hours; outside study, eight hours. Designed for graduate environmental engineering program students. Physical chemistry and mass transfer fundamentals related to contaminant fate and transport in soil, air, and water systems, including soil/water/solid sorption and desorption, oxidation, vaporization, gas solubility, and dissolution of nonaqueous phase liquids (NAPL), and other environmental systems. Letter grading. Mr. Stolzenbach (Not offered 2012-13)

265B. Contaminant Transport in Soils and
Groundwater. (4) Lecture, four hours; computer applica-
tions, two hours; outside study, six hours. Required sites: courses 250B, 256A. Principles of mass transfer as they apply in soil and groundwater, independent estimation of transport model parameters, and remediation of hazardous waste sites. Letter grading. Mr. Stolzenbach (Not offered 2012-13)

266. Environmental Biotechnology. (4) Lecture, four hours; computer applications, eight hours. Required sites: courses 153, 254A. Environmental biotechnology—concept and potential, biotechnology of pollution control, bioremediation, biomass conversion: composting, biogas and bioethanol production. Letter grading. Ms. Mahendra (Sp)

267. Environmental Applications of Geochemical Modeling. (4) Lecture, four hours; computer applications, eight hours. Required site: course 254A. Computer models are important tools for predicting environmental impacts of contamination. Hands-on experience in modeling using geochemical software packages commonly found in environmental consulting industry to gain better understanding of governing geochemi-
cal principles pertaining to movement and transfor-
mation of contaminants. Types of modeling include speciation, mineral solubility, surface complexation, reaction path, inverse mass balance, and reactive transport modeling. Case studies involve acid mine drainage, nuclear waste disposal, bioavailability and risk assessment, mine tailings and mining waste, deep geologic carbon sequestration, and microbial respiration. Research/modeling project required. Letter grading. Ms. Jay (Sp)

297. Seminar: Current Topics in Civil Engineer-
ing. (2 to 4) Seminar, to be arranged. Discussion of current research and literature in research specialty of faculty member teaching course. S/U grading. (F,W,Sp)

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate civil engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation/apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading. (F,W,Sp)

495. Teaching Assistant Training Seminar. (2) Seminar, two hours. Preparation: appointment as teaching assistant in Civil and Environmental Engineering Department. Seminar on communication of civil engineering principles, concepts, and methods; teaching assistant preparation, organization, and present-
ation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading.

596. Directed Individual or Tutorial Studies. (2 to 8) Tutorial, to be arranged. Limited to graduate civil engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

597A. Preparation for M.S. Comprehensive Exam-
ination. (1 to 12) Tutorial, to be arranged. Limited to graduate civil engineering students. Reading and preparation for M.S. comprehensive examination. S/U grading.

597B. Preparation for Ph.D. Preliminary Examina-
tions. (1 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Reading and preparation for preliminary examinations. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Exam-
ination. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Preparation for oral qualifying examination, including preliminary re-
sessment. S/U grading.

598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate civil engineering students. Supervised independent research for M.S. candidates, including thesis pro-
spects. S/U grading.

599. Research for and Preparation of Ph.D. Dis-
sertation. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Supervised independent research for Ph.D. candidates, including dissertation. S/U grading.
Assistant Professors
Tyson Condie, Ph.D.
Alexander Sherstov, Ph.D.
Zhuowen Tu, Ph.D.
Jennifer W. Vaughan, Ph.D. (Symantec Term Professor of Computer Science)

Senior Lecturer
Leon Levine, M.S., Emeritus

Lecturers S.O.E.
Paul R. Eggert, Ph.D.
David A. Smallberg, M.S.

Adjunct Professors
Alan Kay, Ph.D.
Eddie Kohler, Ph.D.
Rupak Majumdar, Ph.D.
Carey S. Nachenbergs, M.S.
Ani Nahapetian, Ph.D.
Peter S. Pao, Ph.D.
Giovanni Pau, Ph.D.
Peter L. Reiter, Ph.D.
M. Yahya Sanadidi, Ph.D.

Scope and Objectives
Computer science is concerned with the design, modeling, analysis, and applications of computer-related systems. Its study at UCLA provides education at the undergraduate and graduate levels necessary to understand, design, implement, and use software and hardware of digital computers and digital systems. The programs provide comprehensive and integrated studies of subjects in computer system architecture, computer networks, distributed computer systems, programming languages and software systems, information and data management, artificial intelligence, computer science theory, computational systems biology and bio-informatics, and computer vision and graphics.

The undergraduate and graduate studies and research projects in computer science are supported by significant computing resources. In addition to the departmental computing facility, there are over a dozen research laboratories specializing in areas such as distributed systems, multimedia computer communications, distributed sensor networks, VLSI systems, VLSI CAD, embedded and reconfigurable systems, computer graphics, bio-informatics, and artificial intelligence. Also, the Cognitive Systems Laboratory is engaged in studying computer systems that emulate or support human reasoning. The Biocybernetics Laboratory is devoted to multidisciplinary research involving the application of engineering and computer science methods to problems in biology and medicine.

The B.S. degree may be attained either through the Computer Science and Engineering major or through the Computer Science major described below.

In addition to the B.S. in Computer Science and Engineering and the B.S. in Computer Science, HSSEAS offers M.S. and Ph.D. degrees in Computer Science, as well as minor fields for graduate students seeking engineering degrees. In cooperation with the John E. Anderson Graduate School of Management, the Computer Science Department offers a concurrent degree program that enables students to obtain the M.S. in Computer Science and the M.B.A. (Master of Business Administration).

Department Mission
The Computer Science Department strives for excellence in creating, applying, and imparting knowledge in computer science and engineering through comprehensive educational programs, research in collaboration with industry and government, dissemination through scholarly publications, and service to professional societies, the community, state, and nation.

Computer Science and Engineering Undergraduate Program Objectives
The computer science and engineering program is accredited by the Engineering Accreditation Commission and the Computing Accreditation Commission of ABET, http://www.abet.org.

The computer science and engineering undergraduate program educational objectives are that our alumni (1) make valuable technical contributions to design, development, and production in the practice of computer science and computer engineering, in related engineering or application areas, and at the interface of computers and physical systems, (2) demonstrate strong communication skills and the ability to function effectively as part of a team, (3) demonstrate a sense of societal and ethical responsibility in their professional endeavors, and (4) engage in professional development or postgraduate education to pursue flexible career paths amidst technological changes.

Computer Science Undergraduate Program Objectives
The computer science program is accredited by the Computing Accreditation Commission of ABET, http://www.abet.org.

The computer science undergraduate program educational objectives are that our alumni (1) make valuable technical contribu-
tions to design, development, and production in their practice of computer science and related engineering or application areas, particularly in software systems and algorithmic methods, (2) demonstrate strong communication skills and the ability to function effectively as part of a team, (3) demonstrate a sense of societal and ethical responsibility in their professional endeavors, and (4) engage in professional development or postgraduate education to pursue flexible career paths amid future technological changes.

**Undergraduate Study**

The Computer Science and Engineering and Computer Science majors are designated capstone majors. Computer Science and Engineering students complete a major product design course, while Computer Science students complete either a software engineering or major product design course. Graduates are expected to apply the basic mathematical and scientific concepts that underlie modern computer science and engineering; design a software or digital hardware system, component, or process to meet desired needs within realistic constraints; function productively with others as part of a team; identify, formulate, and solve computer software- and hardware-related engineering problems; and demonstrate effective communication skills.

**Computer Science and Engineering B.S.**

**Capstone Major**

The computer science and engineering curriculum at UCLA provides the education and training necessary to design, implement, test, and utilize the hardware and software of digital computers and digital systems. The curriculum has components spanning both the Computer Science and Electrical Engineering Departments. Within the curriculum students study all aspects of computer systems from electronic design through logic design, MSI, LSI, and VLSI concepts and device utilization, machine language design, implementation and programming, operating system concepts, systems programming, networking fundamentals, higher-level language skills, and application of these to systems. Students are prepared for employment in a wide spectrum of high-technology industries.

**Preparation for the Major**

*Required:* Chemistry and Biochemistry 20A; Computer Science 1, 31, 32, 33, 35L, M51A (or Electrical Engineering M16); Electrical Engineering 1, 2, 10; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 4AL, 4BL.

**The Major**

*Required:* Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), M152A (or Electrical Engineering M116L), 180, 181, Electrical Engineering 102, 110, 110L, 115A, 115C, Statistics 100A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Computer Science 152B); and three upper division computer science elective courses (12 units), one of which must be selected from Computer Science 143 or 161 or 174A. The remaining two elective courses must be selected from Computer Science 112, 113, 114, M117 (or Electrical Engineering M117), CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130, 132, 133, 136, 143, 144, 151C, 161, 170A, M171L (or Electrical Engineering M171L), 174A, 174B, 174C, 183, M184 (or Bioengineering M184 or Computational and Systems Biology M184), CM186 (or Bioengineering CM186 or Computational and Systems Biology M186), CM187 (or Bioengineering CM187 or Computational and Systems Biology M187). Electrical Engineering 103 may be substituted for one elective (credit is not given for both Computer Science 170A and Electrical Engineering 103 unless one of the courses is included in the technical breadth area); 4 units of either Computer Science 194 or 199 may be applied as an elective by petition.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

**Computer Science B.S.**

**Capstone Major**

The computer science curriculum is designed to accommodate students who want professional preparation in computer science but do not necessarily have a strong interest in computer systems hardware. The curriculum consists of components in computer science, a minor or technical support area, and a core of courses from the social sciences, life sciences, and humanities. Within the curriculum, students study subject matter in software engineering, principles of programming languages, data structures, computer architecture, theory of computation and formal languages, operating systems, distributed systems, computer modeling, computer networks, compiler construction, and artificial intelligence. Majors are prepared for employment in a wide range of industrial and business environments.

**Preparation for the Major**

*Required:* Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), M152A (or Electrical Engineering M116L), 180, 181, Statistics 100A; three science and technology courses (12 units) not used to satisfy other requirements, that may include three upper division computer science courses or three courses selected from an approved list available in the Office of Academic and Student Affairs; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone software engineering or design course from Computer Science 130 or 152B; and six upper division computer science elective courses (24 units), two of which must be selected from Computer Science 143, 161, or 174A and one of which must be from 112 or 170A or Electrical Engineering 103 (credit is not given for both Computer Science 170A and Electrical Engineering 103 unless one of the courses is included in the technical breadth area). For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.
must be 132; 4 units of either Computer Science 194 or 199 may be applied as an elective by petition.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ee/.

**Bioinformatics Minor**

The Bioinformatics minor introduces undergraduate students to the emerging interdisciplinary field of bioinformatics, an active area of research at UCLA combining elements of the computational sciences with the biological sciences. The minor organizes the many course offerings in different UCLA departments into a coherent course plan providing students with significant training in bioinformatics in addition to the training they obtain from their major. Students who complete the minor will be strong candidates for admission to Ph.D. programs in bioinformatics as well as have the relevant training to obtain jobs in the biotechnology industry.

Students complete a core curriculum and an elective course and are strongly encouraged to participate in undergraduate research as early as possible in one of the many groups offering research opportunities in bioinformatics.

To enter the minor, students must be (1) in good academic standing (2.0 grade point average or better) and (2) file a petition in the Office of Academic and Student Affairs of the Henry Samueli School of Engineering and Applied Science, 6426 Boelter Hall; or, for College life or other natural sciences students, in the administrative office of the Computational and System Biology IDP, 4436 Boelter Hall.

**Required Lower Division Courses (14 units minimum):** Computer Science 32 or Program in Computing 10C, Life Sciences 3, 23L, Mathematics 33A.

**Required Upper Division Courses (18 units minimum):** Computational and Systems Biology M184, Computer Science CM121 (or Chemistry and Biochemistry CM160A), CM124 (or Human Genetics CM124), 180 (or Mathematics 182), and one bioinformatics elective course selected from Computational and Systems Biology M186, Computer Science CM122, 170A, Ecology and Evolutionary Biology 135, Electrical Engineering 102, 141, Human Genetics C144, Molecular, Cell, and Developmental Biology 144, 172, Physiological Science 125, Statistics 100A, 100B.

Students are strongly encouraged to take Computer Science M184 as early as possible to obtain an overview of computational biology.

A minimum of 20 units applied toward the minor requirements must be in addition to units applied toward major requirements or another minor.

No more than two upper division courses may be applied toward both this minor and a major or minor in another department or program. If students complete some of the minor requirements as part of their major program, they can take additional courses from the bioinformatics elective course list. All minor courses must be taken for a letter grade, and students must have a minimum grade of C (2.0) in each and an overall C average. Successful completion of the minor is indicated on the transcript and diploma.

**Graduate Study**

For information on graduate admission, see Graduate Programs, page 23.

The following introductory information is based on the 2012-13 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gsaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

The Department of Computer Science offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Computer Science and participates in a concurrent degree program (Computer Science M.S./Management M.B.A.) with the John E. Anderson Graduate School of Management.

**Computer Science M.S.**

**Course Requirements**

**Course Requirement.** A total of nine courses is required for the M.S. degree, including a minimum of five graduate courses. No specific courses are required, but a majority of both the total number of formal courses and the total number of graduate courses must consist of courses offered by the Computer Science Department.

**Undergraduate Courses.** No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, 199; Materials Science and Engineering 110, 120, 130, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.
**Breadth Requirement.** M.S. degree students must satisfy the computer science breadth requirement by the end of the third term in graduate residence at UCLA. The requirement is satisfied by mastering the contents of five undergraduate courses or equivalent: Computer Science 180, two courses from 111, 118, and M151B, one course from 130, 131, or 132, and one course from 143, 161, or 174A. A UCLA undergraduate course taken by graduate students cannot be used to satisfy graduate degree requirements if students have already received a grade of B– or better for a course taken elsewhere that covers substantially the same material.

For the M.S. degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory. Competence in any or all courses in breadth requirements may be demonstrated in one of three ways:

1. Satisfactory completion of the course at UCLA with a grade of B– or better
2. Satisfactory completion of an equivalent course at another university with a grade of B– or better
3. Satisfactory completion of a final examination in the course at UCLA

**Comprehensive Examination Plan**

In the comprehensive examination plan, at least five of the nine courses must be 200-series courses. The remaining four courses may be either 200-series or upper division courses. No units of 500-series courses may be applied toward the comprehensive examination plan requirements.

**Thesis Plan**

In the thesis plan, seven of the nine courses must be formal courses, including at least four from the 200 series. The remaining two courses may be 598 courses involving work on the thesis.

The thesis is a report on the results of student investigation of a problem in the major field of study under the supervision of the thesis committee, which approves the subject and plan of the thesis and reads and approves the complete manuscript. While the problem may be one of limited scope, the thesis must exhibit a satisfactory style, organization, and depth of understanding of the subject. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

**Computer Science M.S./Management M.B.A.**

The Department of Computer Science and the John E. Anderson Graduate School of Management offer a concurrent degree program that enables students to complete the requirements for the M.S. in Computer Science and the M.B.A. (Master of Business Administration) in three academic years. Students should request application materials from both the M.B.A. Admissions Office, John E. Anderson Graduate School of Management, and the Department of Computer Science.

**Computer Science Ph.D.**

**Major Fields or Subdisciplines**

Artificial intelligence; computational systems biology; computer networks; computer science theory; computer system architecture; graphics and vision; information and data management; and software systems.

**Course Requirements**

Normally, students take courses to acquire the knowledge needed to prepare for the written and oral examinations and for conducting Ph.D. research. The basic program of study for the Ph.D. degree is built around the major field requirement and two minor fields. The major field and at least one minor field must be in computer science. The fundamental examination is common for all Ph.D. candidates in the department and is also known as the written qualifying examination.

To satisfy the major field requirement, students are expected to attain a body of knowledge contained in six courses, as well as the current literature in the area of specialization. In particular, students are required to take a minimum of four graduate courses in the major field of Ph.D. research, selecting these courses in accordance with guidelines specific to the major field. Guidelines for course selection in each major field are available from the departmental Student Affairs Office. Grades of B– or better, with a grade-point average of at least 3.33 in all courses used to satisfy the major field requirement, are required. Students are required to satisfy the major field requirement within the first nine terms after enrolling in the graduate program.

Each minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. By petition and administrative approval, a minor field may be satisfied by examination.

**Breadth Requirement.** Ph.D. degree students must satisfy the computer science breadth requirement by the end of the third term in graduate residence at UCLA. The requirement is satisfied by mastering the contents of five undergraduate courses or equivalent: Computer Science 180, two courses from 111, 118, and M151B, one course from 130, 131, or 132, and one course from 143, 161, or 174A. A UCLA undergraduate course taken by graduate students cannot be used to satisfy graduate degree requirements if students have already received a grade of B– or better for a course taken elsewhere that covers substantially the same material.

For the Ph.D. degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory (in addition to the three terms of 201 that may have been completed for the M.S. degree). Competence in any or all courses may be demonstrated in one of three ways:

1. Satisfactory completion of the course at UCLA with a grade of B– or better
2. Satisfactory completion of an equivalent course at another university with a grade of B– or better
3. Satisfactory completion of a final examination in the course at UCLA

For requirements for the Graduate Certificate of Specialization, see Engineering Schoolwide Programs.

**Written and Oral Qualifying Examinations**

The written qualifying examination consists of a high-quality paper, solely authored by the student. The paper can be either a research paper containing an original contribution or a focused critical survey paper. The paper should demonstrate that the student understands and can integrate and communicate ideas clearly and concisely. It should be approximately 10 pages single-spaced, and the style should be suitable for submission to a first-rate technical conference or journal. The paper must represent work that the student did as a graduate student at UCLA. Any contributions that are not the student’s own, including those of the student’s adviser, must be explicitly acknowledged in detail. Prior to submission, the paper must be reviewed by the student’s adviser on a cover page with the
adviser’s signature indicating review. After submission, the paper must be reviewed and approved by at least two other members of the faculty. There are two deadlines a year for submission of papers.

After passing the preliminary examination and coursework for the major and minor fields, the student should form a doctoral committee and prepare to take the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, must hold appointments in the department. The remaining member must be a UCLA faculty member in another department. The nature and content of the oral qualifying examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Fields of Study

Artificial Intelligence

Artificial intelligence (AI) is the study of intelligent behavior. While other fields such as philosophy, psychology, neuroscience, and linguistics are also concerned with the study of intelligence, the distinguishing feature of AI is that it deals primarily with information processing models. Thus the central scientific question of artificial intelligence is how intelligent behavior can be reduced to information processing. Since even the simplest computer is a completely general information processing device, the test of whether some behavior can be explained by information processing mechanisms is whether a computer can be programmed to produce the same behavior. Just as human intelligence involves gathering sensory input and producing physical action in the world, in addition to purely mental activity, the computer for AI purposes is extended to include sense organs such as cameras and microphones, and output devices such as wheels, robotic arms, and speakers.

The predominant research paradigm in artificial intelligence is to select some behavior that seems to require intelligence on the part of humans, to theorize about how the behavior might be accounted for, and to implement the theory in a computer program to produce the same behavior. If successful, such an experiment lends support to the claim that the selected behavior is reducible to information processing terms, and may suggest the program’s architecture as a candidate explanation of the corresponding human process.

The UCLA Computer Science Department has active research in the following major subfields of artificial intelligence:

1. **Problem Solving.** Analysis of tasks, such as playing chess or proving theorems, that require reasoning about relatively long sequences of primitive actions, deductions, or inferences
2. **Knowledge representation and qualitative reasoning.** Analysis of tasks such as commonsense reasoning and qualitative physics. Here the deductive chains are short, but the amount of knowledge that potentially may be brought to bear is very large
3. **Expert systems.** Study of large amounts of specialized or highly technical knowledge that is often probabilistic in nature. Typical domains include medical diagnosis and engineering design
4. **Natural language processing.** Symbolic, statistical, and artificial neural network approaches to text comprehension and generation
5. **Computer vision.** Processing of images, as from a TV camera, to infer spatial properties of the objects in the scene (three-dimensional shape), their dynamics (motion), their photometry (material and light), and their identity (recognition)
6. **Robotics.** Translation of a high-level command, such as picking up a particular object, into a sequence of low-level control signals that might move the joints of a robotic arm/hand combination to accomplish the task; often this involves using a computer vision system to locate objects and provide feedback
7. **Machine learning.** Study of the means by which a computer can automatically improve its performance on a task by acquiring knowledge about the domain
8. **Parallel architecture.** Design and programming of a machine with thousands or even millions of simple processing elements to produce intelligent behavior; the human brain is an example of such a machine

Computational Systems Biology

The computational systems biology (CSB) field can be selected as a major or minor field for the Ph.D. or as a specialization area for the M.S. degree in Computer Science. Graduate studies and research in the CSB field are focused on computational modeling and analysis of biological systems and biological data.

Core coursework is concerned with the methods and tools development for computational, algorithmic, and dynamic systems network modeling of biological systems at molecular, cellular, organ, whole organism, or population levels—and leveraging them in biosystem and bioinformatics applications. Methodological studies include bioinformatics and systems biology modeling, with focus on genomics, proteomics, metabolomics, and higher levels of biological/physiological organization, as well as multiscale approaches integrating the parts. Typical research areas with a systems focus include molecular and cellular systems biology, organ systems physiology, medical, pharmacological, pharmacokinetic (PK), pharmacodynamic (PD), toxicokinetic (TK), physiologically based PBPK-PD, PBTK, and pharmacogenomic system studies; neurosystems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. Typical research areas with a bioinformatics focus include development of computational methods for analysis of high-throughput molecular data, including genomic sequences, gene expression data, protein-protein interaction, and genetic variation. These computational methods leverage techniques from both statistics and algorithms.

Computer Networks

The computer networks field involves the study of computer networks of different types, in different media (wired, wireless), and for different applications. Besides the study of network architectures and protocols, this field also emphasizes distributed algorithms, distributed systems, and the ability to evaluate system performance at various levels of granularity (but principally at the systems level). In order to understand and predict systems behavior, mathematical models are pursued that lead to the evaluation of system throughput, response time, utilization of devices, flow of jobs and messages, bottlenecks, speedup, power, etc. In addition, students are taught to design and implement computer networks using formal design methodologies subject to appropriate cost and objective functions. The tools required to carry out this design include probability theory, queueing theory, distributed systems theory, mathematical programming, control theory, operating systems design, simulation methods, measurement tools, and heuristic design proce-
dures. The outcome of these studies provides the following:

1. An appropriate model of the computer system under study
2. An adequate (exact or approximate) analysis of the behavior of the model
3. The validation of the model as compared to simulation and/or measurement of the system
4. Interpretation of the analytical results in order to obtain behavioral patterns and key parameters of the system

5. Design methodology

Resource Allocation

A central problem in the design and evaluation of computer networks deals with the allocation of resources among competing demands (e.g., wireless channel bandwidth allocation to backlogged stations). In fact, resource allocation is a significant element in most of the technical (and nontechnical) problems we face today. Most of our resource allocation problems arise from the unpredictability of the demand for the use of these resources, as well as from the fact that the resources are geographically distributed (as in computer networks). The computer networks field encounters such resource allocation problems in many forms and in many different computer system configurations. Our goal is to find allocation schemes that permit suitable concurrency in the use of devices (resources) so as to achieve efficiency and equitable allocation. A very popular approach in distributed systems is allocation on demand, as opposed to prescheduled allocation. On-demand allocation is found to be effective, since it takes advantage of statistical averaging effects. It comes in many forms in computer networks and is known by names such as asynchronous time multiplexing, packet switching, frame relay, random access, and so forth.

Computer Science Theory

Computer science is in large measure concerned with information processing systems, their applications, and the corresponding problems of representation, transformation, and communication. The computer science fields are concerned with different aspects of such systems, and each has its own theoretical component with appropriate models for description and analysis, algorithms for solving the related problems, and mathematical tools. Thus in a certain sense computer science theory involves all of computer science and participates in all disciplines.

The term theoretical computer science has come to be applied nationally and intentionally to a certain body of knowledge emphasizing the interweaving themes of computability and algorithms, interpreted in the broadest sense. Under computability, one includes questions concerning which tasks can and cannot be performed by information systems of different types restricted in various ways, as well as the mathematical analysis of such systems, their computations, and the languages for communication with them. Under algorithms, one includes questions concerning (1) how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), (2) how efficiently a proposed system performs a task in terms of resources used, and (3) the limits on how efficiently a task can be performed. These questions are often addressed by first developing models of the relevant parts of an information processing system (e.g., the processors, their interconnections, their rules of operation, the means by which instructions are conveyed to the system, or the way the data is handled) or of the input/output behavior of the system as a whole. The properties of such models are studied both for their own interest and as tools for understanding the system and improving its performance or applications.

Computer System Architecture

Computer system architecture deals with the design, implementation, and evaluation of computer systems and their building blocks. It deals with general-purpose systems as well as embedded special-purpose systems. The field also encompasses the development of tools to enable system designers to describe, model, fabricate, and test highly complex computer systems.

Computer systems are implemented as a combination of hardware and software. Hence, research in the field of computer architecture often involves both hardware and software issues. The requirements of application software and operating systems, together with the capabilities of compilers, play a critical role in determining the features implemented in hardware. At the same time, the computer architect must also take into account the capabilities and limitations of the underlying implementation technology as well as of the design tools.

The goal of research in computer architecture is to develop building blocks, system organizations, design techniques, and design tools that lead to improved performance and reliability as well as reduced power consumption and cost.

Corresponding to the richness and diversity of computer systems architecture research at UCLA, a comprehensive set of courses is offered in the areas of advanced processor architecture, arithmetic processor systems, parallel and distributed architectures, fault-tolerant systems, reconfigurable systems, embedded systems, and computer-aided design of VLSI circuits and systems.

1. Novel architectures encompass the study of computations that are performed in ways that are quite different than those used by conventional machines. Examples include various domain-specific architectures characterized by high computational rates, low power, and reconfigurable hardware implementations.

2. The study of high-performance processing algorithms deals with algorithms for very high-performance numerical processing. Techniques such as redundant-digit representations of number systems, fast arithmetic, and the use of highly parallel arrays of processing elements are studied with the goal of providing the extremely high processing speeds required in a number of upcoming computer applications.

3. The study of computational algorithms and structures deals with the relationship between computational algorithms and the physical structures that can be employed to carry them out. It includes the study of interconnection networks, and the way that algorithms can be formulated for efficient implementation where regularity of structure and simplicity of interconnections are required.

4. Computer-aided design of VLSI circuits and systems is an active research area that develops techniques for the automated synthesis and analysis of large-scale systems. Topics include high-level and logic-level synthesis, tech-
nology mapping, physical design, interconnect modeling, and optimization of various VLSI technologies such as full-custom designs, standard cells, programmable logic devices (PLDs), multichip modules (MCMs), system-on-a-chip (SoCs), network-on-a-chip (NoC), system-in-a-package (SiPs), and design for nanotechnologies.

5. VLSI architectures and implementation is an area of current interest and collaboration between the Electrical Engineering and Computer Science Departments that addresses the impact of large-scale integration on the issues of computer architecture. Application of these systems in medicine and healthcare, multimedia, and finance is being studied in collaboration with other schools on campus.

Graphics and Vision

Information and Data Management
The information and data management field focuses on basic problems of modeling and managing data and knowledge, and their relation with other fundamental areas of computer science, such as operating systems and networking, programming languages, and human-computer interface design.

A data management system embodies a collection of data, devices in which the data are stored, and logic or programs used to manipulate that data. Information management is a generalization of data management in which the data being stored are permitted to be arbitrarily complex data structures, such as rules and trees. In addition, information management goes beyond simple data manipulation and query and includes inference mechanisms, explanation facilities, and support for distributed and web-based access.

The need for rapid, accurate information is pervasive in all aspects of modern life. Modern systems are based on the coordination and integration of multiple levels of data representation, from characteristics of storage devices to conceptual and abstract levels. As human enterprises have become more complex, involving more complicated decisions and trade-offs among decisions, the need for sophisticated information and data management has become essential.

Software Systems
The programming languages and systems field is concerned with the study of theory and practice in the development of software systems. Well-engineered systems require appreciation of both principles and architectural trade-offs. Principles provide abstractions and rigor that lead to clean designs, while systems-level understanding is essential for effective design.

Principles here encompass the use of programming systems to achieve specified goals, the identification of useful programming abstractions or paradigms, the development of comprehensive models of software systems, and so forth. The thrust is to identify and clarify concepts that apply in many programming contexts.

Development of software systems requires an understanding of many methodological and architectural issues. The complex systems developed today rely on concepts and lessons that have been extracted from years of research on programming languages, operating systems, database systems, knowledge-based systems, real-time systems, and distributed and parallel systems.

Facilities
Departmental laboratory facilities for instruction and research include:

Artificial Intelligence Laboratories
Artificial Intelligence Laboratory
The Artificial Intelligence Laboratory is used for investigating knowledge representation systems, pattern recognition, expert systems, intelligent user agents, planning, problem solving, heuristic search, and related areas.

Cognitive Systems Laboratory
The Cognitive Systems Laboratory is used for studying systems that emulate human cognition, especially learning, planning, and reasoning under uncertainty. Topics include causal reasoning, knowledge discovery, knowledge compilation, physical systems diagnosis, and automated explanation. See http://singapore.cs.ucla.edu.

Collaborative Design Laboratory
The Collaborative Design Laboratory is used for investigating methods for effective computer support of small teams involved in design and research.

Computational Systems Biology Laboratories
Biocybernetics Laboratory
The Biocybernetics Laboratory emphasizes integrative, interdisciplinary computational biology and experimentation in life sciences, medicine, physiology, and pharmacology. Laboratory pedagogy involves development and exploitation of the synergistic and methodologic interface between modeling and laboratory data and experimentation, and integrated approaches for solving complex bio-system problems from sparse biodata. See http://biocyb.cs.ucla.edu.

Biomedical Engineering Laboratory
The Biomedical Engineering Laboratory was established jointly by HSSEAS and the School of Medicine to support courses and research projects in health care information systems, covering issues in user requirement specifications, image data processing and retrieval, feature abstraction, simulation and analysis, visualization, and systems integration.

Computational Cardiology Laboratory
The Computational Cardiology Laboratory is a computational laboratory for mathematical modeling and computer simulation of cardiac systems in normal and pathological conditions. The goals of laboratory researchers are twofold: to find the mechanism of heart fibrillation, the main cause of sudden cardiac death; and to improve the efficiency of computer simulation by using parallel computer architecture with specially-developed numerical algorithms. All research is carried out in collaboration with the UCLA Cardiology Department.

Human/Computer Interface Laboratory
The Human/Computer Interface Laboratory focuses on the use of cognitive science concepts to design more reliable user-friendly interfaces with computer and communication systems and the modeling and visualization of scientific data. See http://www.cs.ucla.edu/hcip/.

Computer Graphics and Vision Laboratories
Center for Image and Vision Science (CIVS)
The Center for Image and Vision Science supports interdisciplinary research between the departments of Statistics and Computer Science in various aspects of visual modeling and inference. See http://civs.stat.ucla.edu/research.html.
The CENS Systems Laboratory is used for research on the architectural challenges posed by massively distributed, large-scale, physically coupled, and usually untethered and small-form-factor computing systems. Through prototype implementations and simulation, such issues as data diffusion protocols, localization, time synchronization, low-power wireless communications, and self-configuration are explored. See http://lecs.cs.ucla.edu.

The UCLA Vision Laboratory is used for computer vision research, in particular the processing of sensory information to retrieve mathematical models of the environment in order for machines to interact with it. Applications include shape analysis, visual motion analysis, visual recognition, 3-D reconstruction, and vision-based control (for instance, autonomous vehicle navigation). See http://vision.ucla.edu.


The Computer Communications Laboratory is used for investigating local-area networks, packet-switching networks, and packet-radio networks.

The High-Performance Internet Laboratory is used for investigating high-performance quality of service (QoS) techniques in the Internet, including QoS routing in Internet domains, QoS fault-tolerant multicast, TCP congestion control, and gigabit network measurements. See http://www.cs.ucla.edu/NRL/hipv/.

The Internet Research Laboratory is used for exploring the forefront of current Internet architecture and protocol development, including quantifying the dynamics in large-scale networks and securing large-scale systems such as the Internet routing infrastructure and Domain Name System (DNS). See http://irl.cs.ucla.edu.

The Network Research Laboratory is used for investigating wireless local-area networks (with specific interest in ad-hoc networks, vehicular networks, and personal-area networks) and the interaction between wired and wireless network layers, middleware, and applications. Activities include protocol development, protocol analysis and simulation, and wireless testbed experiments. See http://www.cs.ucla.edu/NRL/wireless/.

The Data Mining Laboratory is used for extracting knowledge from databases. Activities include data mining, artificial intelligence, and database management. See http://www.cs.ucla.edu/ManLib/.

The Computer Systems Architecture Laboratories

The Concurrent Systems Laboratory is used for investigating the design, implementation, and evaluation of computer systems that use state-of-the-art technology to achieve high performance and high reliability. Projects involve both software and hardware, and often focus on parallel and distributed systems in the context of general-purpose as well as embedded applications. See http://www.cs.ucla.edu/csd/research/labs/csl/.

The Digital Arithmetic and Reconfigurable Architecture Laboratory is used for fast digital arithmetic (theory, algorithms, and design) and numerically intensive computing on reconfigurable hardware. Research includes floating-point arithmetic, online arithmetic, application-specific architectures, and design tools. See http://arith.cs.ucla.edu

The Embedded and Reconfigurable System Design Laboratory is used for studying reconfigurable cores in embedded systems that provide the required adaptability and reconﬁgurability, and the design and CAD aspects of low-power embedded systems. See http://er.cs.ucla.edu.

The VLSI CAD Laboratory is used for computer-aided design of VLSI circuits and systems. Areas include high-level and logic-level synthesis, technology mapping, physical design, interconnect modeling and optimization of various VLSI technologies such as full-custom designs, standard cells, programmable logic devices (PLDs), multichip modules (MCMs), system-on-a-chip (SOCs), system-in-a-package (SiPs), and design for nanotechnologies. See http://cadlab.cs.ucla.edu.

The Theory Laboratory is used for developing theoretical foundations for all areas of computer science. Activities include fundamental research into algorithms, computational complexity, distributed computing, cryptography, hardware and software security, quantum computing, biological computing, machine learning, and computational geometry.
Knowledge-Based Multimedia Medical Distributed Database Systems Laboratory
The Knowledge-Based Multimedia Medical Distributed Database Systems Laboratory is used for developing new methodologies to access multimedia (numeric, text, image/picture) data by content and feature rather than by artificial keys such as patient ID. See http://www.kmed.cs.ucla.edu.

Multimedia Stream System Laboratory
The Multimedia Stream System Laboratory is used for investigation and development of stream-based data model constructs and the corresponding querying facilities in response to the growing requirements of advanced multimedia database applications. See http://www.mmsss.cs.ucla.edu.

Multimedia Systems Laboratory
The Multimedia Systems Laboratory is used for research on all aspects of multimedia: physical and logical modeling of multimedia objects, real-time delivery of continuous multimedia, operating systems and networking issues in multimedia systems, and development of multimedia courseware. See http://www.mmsss.cs.ucla.edu.

UCLA Web Information Systems Laboratory
The UCLA Web Information Systems Laboratory is used for investigating Web-based information systems. The laboratory seeks to develop the enabling technology for such systems by integrating the Web with database systems. Current projects focus on the preservation and warehousing of XML and database information to support temporal queries on historical archives, and data systems management systems to support advanced queries and data mining applications on the massive streams of information that are continuously flowing through the Web. See http://wis.cs.ucla.edu.

Software Systems Laboratories
Compilers Laboratory
The Compilers Laboratory is used for research into compilers, embedded systems, and programming languages.

Distributed Simulation Laboratory
The Distributed Simulation Laboratory is used for research on operating system support and applications and utilization of special architectures such as the Intel Hypercube.

Laboratory for Advanced System Research
The Laboratory for Advanced System Research is used for developing advanced operating systems, distributed systems, and middleware and conducting research in systems security.

Parallel Computing Laboratory
The Parallel Computing Laboratory is used for research in scalable simulation, providing an efficient lightweight simulation language, as well as tools for large-scale parallel simulation on modern supercomputers. See http://pcl.cs.ucla.edu.

Software Systems Laboratory
The Software Systems Laboratory is used for research into the design, implementation, and evaluation of operating systems, networked systems, programming languages, and software engineering tools. Some of these research laboratories also provide support for upper division and/or graduate courses.

Computing Resources
In summarizing the resources now available to conduct experimentally based research in the UCLA Computer Science Department, it is useful to identify the major components of the research environment: the departmental computing facility, other hardware and software systems, administrative structure, and technical support staff.

Hardware
Computing facilities range from large campus-operated supercomputers to a major local network of servers and workstations that are administered by the department computing facilities (DCF) or school network (SEASnet). The departmental research network includes Oracle servers and shared workstations, on the school's own ethernet TCP/IP local network. A wide variety of peripheral equipment is also part of the facility, and many more research-group workstations share the network; the total number of machines exceeds 700, the majority running the Linux operating system. The network consists of switched 10/100/1000 ethernet to the desktop with a gigabit backbone connection. The department LAN is connected to the campus gigabit backbone. An 802.11g wireless network is also available to faculty, staff, and graduate students.

Administrative Structure
The central facilities and wide-area networking are operated by the campuswide Communications Technology Services. Access to the departmental and SEASnet machines is controlled so as to maximize the usefulness of these computers for education and research, but no direct charges are involved.

Technical Support Staff
The support staff consists of hardware and software specialists. The hardware laboratory supports network connections, configures routers, switches, and network monitoring tools. The software group administers the department UNIX servers, providing storage space and backup for department users.

Faculty Areas of Thesis Guidance

Professors
Jason (Jingsheng) Cong, Ph.D. (Illinois, 1990)
Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies
Adnan Y. Darwiche, Ph.D. (Stanford, 1993)
Knowledge representation and automated reasoning (symbolic and probabilistic), applications to diagnosis, prediction, planning, and verification
Joseph D. DiStefano III, Ph.D. (UCLA, 1966)
Biocybernetics; computational systems biology; dynamic biosystems modeling, simulation, clinical therapy and experiment design optimization methodologies; pharmacokinetic (PK), pharmacodynamic (PD), and physiologically-based PK (PBPK) modeling; knowledge-based (expert) systems for life science research
Michael G. Dyer, Ph.D. (Yale, 1982)
Artificial intelligence: natural language processing; connectionist, cognitive, and animat-based modeling
Milos D. Ercegovac, Ph.D. (Illinois, 1975)
Application-specific architectures, digital computer arithmetic, digital design, low-power systems, reconfigurable systems
Deborah L. Estrin, Ph.D. (MIT, 1985)
Sensor networks, embedded network sensing, environmental monitoring, computer networks
Eliezer M. Gafni, Ph.D. (MIT, 1982)
Computer communication, networks, mathematical programming algorithms
Mario Gerla, Ph.D. (UCLA, 1973)
Wireless ad-hoc networks; MAC, routing and transport protocols, vehicular communications, peer-to-peer mobile networks, personal-area networks (Bluetooth and Zigbee), underwater sensor networks, Internet transport protocols (TCP streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocol performance evaluation
Problem solving, heuristic search, planning in artificial intelligence
Christopher J. Lee, Ph.D. (Stanford, 1993)
Bioinformatics and information theory of experiment planning, inference, and evolution

* Also Professor of Medicine
Songwu Lu, Ph.D. (Illinois, 1999)
Integrated-service support over heterogeneous networks, e.g., mobile computing environments, Internet and Ad Hoc networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics.

Scientific computing and applied mathematics.

†Rafail Ostrovsky, Ph.D. (MIT, 1992)
Theoretical computer science, algorithms, cryptography, complexity theory, randomization, network protocols, geometric algorithms, data mining.

Jens Palsberg, Ph.D. (Aarhus U., Denmark, 1992)
Compilers, embedded systems, programming languages.

D. Scott Parker, Jr., Ph.D. (Illinois, 1978)
Data mining, information modeling, scientific computing, bioinformatics, database and knowledge-based systems.

Modrag Polonijak, Ph.D. (UC Berkeley, 1991)
Computer-aided analysis and synthesis of system level designs, behavioral synthesis, and interaction between high-performance application-specific computations and communications.

Atit Sahai, Ph.D. (MIT, 2000)
Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory.

Majid Sarrafzadeh, Ph.D. (Illinois, 1987)
Computer engineering, embedded systems, VLSI CAD, algorithms.

Stefano Soatto, Ph.D. (Caltech, 1996)
Computer vision, shape analysis, motion analysis, texture analysis, 3-D reconstruction, vision-based control, computer graphics, image-based modeling and rendering, medical imaging: registration, segmentation, statistical shape analysis; autonomous systems: sensor-based control, planning non-linear filtering; human-computer interaction: vision-based interfaces, visibility, visualization.

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Energy aware networking and computing, embedded networked sensing, embedded software, low-power wireless systems and applications of wireless and embedded technology.

Demetri Terzopoulos, Ph.D. (MIT, 1984)
Computer graphics, computer vision, medical image analysis, computer-aided design, artificial life/intelligence.

Wei Wang, Ph.D. (UCLA, 1999)
Data mining, bioinformatics and computational biology, databases.

Alan L. Yuille, Ph.D. (U. Cambridge, United Kingdom, 1986)
Computer vision, computational models of cognition, machine learning.

Carlo A. Zaniolo, Ph.D. (UCLA, 1976)
Knowledge bases and deductive databases, parallel execution of PROLOG programs, formal software specifications, distributed systems, artificial intelligence, and computational biology.

Lixia Zhang, Ph.D. (MIT, 1989)
Computer network, Internet architecture, protocol designs, security and resiliency of large-scale systems.

Song-Chun Zhu, Ph.D. (Harvard, 1996)
Computer vision, statistical modeling and computing, vision and visual arts, machine learning.

Professors Emeriti

Digital computer architecture and design, fault-tolerant computing, digital arithmetic.

Rajive L. Bagrodia, Ph.D. (U. Texas, 1987)
Wireless networks, nomadic computing, parallel programming, performance evaluation of computer and communication systems.

Alfonso F. Cardenas, Ph.D. (UCLA, 1969)
Database management, distributed heterogeneous multimedia (text, image, picture, video, voice) systems, information systems planning and development methodologies, software engineering, medical informatics, legal and intellectual property issues.

Jack W. Caryle, Ph.D. (U.C. Berkeley, 1961)
Communication, computer theory and practice, algorithms and complexity, discrete system theory, developmental and probabilistic systems.

Wesley W. Chu, Ph.D. (Stanford, 1966)
Distributed computing, distributed database, memory management, computer communication systems, performance measurement and evaluation of distributed systems and multithreaded packet-switched systems.

Thelma Estrin, Ph.D. (Wisconsin, 1951)
Biomedical engineering, application of technology and computers to health care, computer methods in neuroscience, engineering education.

Shella A. Greibach, Ph.D. (Harvard, 1963)
Theoretical computer science, computational complexity, program schemes and semantics, formal language automata, computability.

Leonard Kleinrock, Ph.D. (MIT, 1963)
Computer networks, computer-communication systems, resource sharing and allocation, computer systems modeling, analysis and design, queuing systems theory and applications, performance evaluation of congestion-prone systems, performance evaluation and design of distributed multiclass packet-switching systems, wireless networks, mobile computing, nomadic computing, and distributed and parallel processing systems.

Allen Klinger, Ph.D. (UC Berkeley, 1966)
Pattern recognition, picture processing, biomedical applications, mathematical modeling.

Lawrence P. McNamee, Ph.D. (Pittsburgh, 1964)
Computer graphics, discrete simulation, digital filtering, computer-aided design, LSI fabrication techniques, printed circuit board design.

Michel A. Melkanoff, Ph.D. (UCLA, 1965)
Programming languages, data structures, database design, relational models, simulation systems, robotics, computer-aided design and manufacturing, numerical-controlled machinery.

Multimedia systems, database systems, data mining.

Judea Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1962)
Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference, and counterfactual analysis.

Digital computer architecture and design, fault-tolerant computing, digital arithmetic.

†Jacques J. Vidal, Ph.D. (U. Paris, Sorbonne, 1961)
Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems' signal processing.

Associate Professors

Jungkoo (John) Cho, Ph.D. (Stanford, 2002)
Databases, web technologies, information discovery and integration.

Eleazar Eskin, Ph.D. (Columbia, 2002)
Bioinformatics, genetics, genomics, machine learning.

Programming language design, static type systems, formal methods, software model checking, compilers.

Glenn D. Reinman, Ph.D. (U.C San Diego, 2001)
Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multicores and multiprocessors.

Amit Sahai, Ph.D. (MIT, 2000)
Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory.

Yuval Tamir, Ph.D. (U.C Berkeley, 1985)
Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection networks and switches, multi-core architectures, reconﬁgurable systems.

Assistant Professors

Tyson Conde, Ph.D. (U.C Berkeley, 2010)
Large-scale distributed data management, declarative languages, systems for machine learning and big data analysis.

Alexander Sherstov, Ph.D. (Texas, Austin, 2009)
Complexity theory with a focus on communication and circuit complexity, computational learning theory, quantum computing.

Zhuowen Tu, Ph.D. (Ohio State, 2002)
Statistical modeling in computational biology, machine learning, brain imaging.

Jennifer W. Vaughan, Ph.D. (U. Pennsylvania, 2009)
Machine learning, computational/algorithms economics, social network theory, algorithms.

Senior Lecturer

Leon Levine, M.S. (MIT, 1949), Emeritus
Computer methodology.

Lecturers S.O.E.

Paul R. Eggert, Ph.D. (UCLA, 1980)
Programming languages, operating systems principles, compilers, Internet.

David A. Smallberg, M.S. (UCLA, 1978)
Programming languages, software development.

Adjunct Professors

Allen Kay, Ph.D. (Utah, 1969)
Object-oriented programming, personal computing, graphical user interfaces.

Rupak Majumdar, Ph.D. (U.C Berkeley, 2003)
Computer-aided verification of hardware and software systems, logic and automatic theorem, embedded, hybrid, and probabilistic systems.

Carey S. Nachenberg, M.S. (UCLA, 1965)
Anti-virus and intrusion detection technology.

Anil Nahapetian, Ph.D. (UCLA, 2007)
Hardware-based system security, embedded systems, mobile and wireless health systems, algorithms for reconfigurable computing.

Peter S. Pao, Ph.D. (U. Michigan, 1975)
Optimizing technology investment and drive growth, knowledge management and technology networking to encourage free flow of knowledge and performance exchange.

Giovanni Pau, Ph.D. (U. Bologna, Italy, 1998)
Protocol design implementation and evaluation for QoS support in wired/wireless networks, and vertical handover protocols and architectures.

Peter L. Reiher, Ph.D. (UCLA, 1987)
Computer networking, path characteristics estimation and applications in flow control, adaptive streaming and overlays design, probability models of computing systems, algorithms and networks.

* Also Professor of Mathematics
† Member of Brain Research Institute
Lower Division Courses

1. Freshman Computer Science Seminar. (1) Seminar, one hour; discussion, one hour. Introduction to department resources and principal topics and key ideas in computer science and computer engineering. Assignments given to bolster independent study and writing skills. Letter grading. Mr. Cong (F)

2. Great Ideas in Computer Science. (4) Lecture, four hours; outside study, eight hours. Broad coverage for liberal arts and social sciences students of computer science theory, technology, and implications, including artificial and neural machine intelligence, computability limits, virtual reality, cellular automata, artificial life, programming languages survey, and philosophical and societal implications. P/NP or letter grading. Mr. Dyer

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

31. Introduction to Computer Science I. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to computer science via theory, applications, and programming. Basic data types, operators and control structures. Input/output. Procedural and data abstraction. Introduction to object-oriented software development. Functions, recursion. Arrays, dynamic data types, object-oriented programming. Examples and exercises from computer science theory and applications. Letter grading. Mr. Palsberg, Mr. Smallberg (W,Sp)


33. Introduction to Computer Organization. (5) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced requisite: course 32. Introductory course on computer architecture, assembly language, and operating systems fundamentals. Number systems, machine language, and assembly language. Program structure; stacks, interrupts, and traps. Assemblers, linkers, and loaders. Operating systems concepts: processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading. Mr. Palsberg, Mr. Reinman (F,Sp)

35L. Software Construction Laboratory. (2) Laboratory, four hours; outside study, two hours. Enforced requisite: course 31. Fundamentals of commonly used software tools and environments, particularly open-source tools to be used in upper division computer science courses. Letter grading. Mr. Eggert, Mr. Palsberg (F,Sp)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical Engineering M16.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading. Mr. Ercegovac, Mr. Potkonjak (F,Sp)

97. Variable Topics in Computer Science. (1 to 4) Lecture, one to four hours; discussion, zero to two hours. Designed for freshmen/sophomores, Variable topics in computer science not covered in regular computer science courses. May be repeated once for credit with topic or instructor change. Letter grading. Mr. Smalberg

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated, P/NP grading.

Upper Division Courses


112. Modeling Uncertainty in Information Systems. (5) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: Statistics 100A. Designed for juniors/seniors. Probability and stochastic process models as applied in computer science. Basic methodological tools include random variables, conditional probability, expectation and higher moments, Bayes theorem, Markov chains. Applications include probabilistic algorithms, evolutionary reasoning, analysis of data structures, reliability, communication protocol and queueing models. Letter grading. Mr. Gerla, Ms. Vaughan (W)

114. Peer-to-Peer Systems. (5) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: courses 122, 118. Optional: courses 111, 218. Fundamental concepts on peer-to-peer networks, such as distributed hashing, routing, searching, and of network management protocols (Join, Leave, death management, routing, table repair). Video streaming and Internet Protocol Television (IPTV) applications, with emphasis on thin clients such as P set-top boxes. Introduction to mesh-based and tree-based topologies for live streaming, with emphasis on key aspects of peer selection, access to streaming content, and optimization techniques (peer capacity, network delay). Hands-on approach to guide students to development and testing of actual experimental system on PlanetLab. Letter grading. Mr. Gerla (W,Sp)

M117. Computer Networks: Physical Layer. (4) (Same as Electrical Engineering M117.) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Not open to students with credit for course M171L. Introduction to fundamental computer communication concepts underlying and supporting modern networks, with focus on wireless communications and media access platforms of network protocol stack. Wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms. Introduction to network models and techniques (peer capacity, network delay). Hands-on approach to guide students to development and testing of actual experimental system on PlanetLab. Letter grading. Mr. Gerla (W)

118. Computer Network Fundamentals. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 32, 33, 35L. Designed for juniors/seniors. Introduction to design and performance evaluation of computer networks, including such topics as what protocols are, layered network architecture, Internet protocol architecture, network applications, transport protocols, routing algorithms and protocols, internetworking, congestion control, and link layer protocols including Ethernet and wireless channels. Letter grading. Mr. Eggert, Mr. Palsberg (F,Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Recommended requisites: course 32 or Program in Computing 10C with grade of C– or better, and Biostatistics 100A or Mathematics 170A or Statistics 100A. Enforced requisite: course CM121 is not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction and application of computational approaches to formulating interdisciplinary problems as computational problems and then solving those problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM221. Letter grading. Mr. Eskin (F)

CM122. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Recommended requisites: course 32 or Program in Computing 10C with grade of C– or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A. Course CM121 is not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction and application of computational approaches to formulating interdisciplinary problems as computational problems and then solving those problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM221. Letter grading. Mr. Eskin (F)

CM124. Computational Genetics. (4) (Same as Human Genetics CM124.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 32, 35L. Recommended: Engineering 183GW or 185GW. Structured programming, program specification, program proving, modularity, abstract data types, computer software tools, software control systems, program testing, team programming. Letter grading. Mr. Eggert, Mr. Majumdar (F,Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: courses 32, 35L. Recommended: Engineering 183GW or 185GW. Structured programming, program specification, program proving, modularity, abstract data types, software tools, software control systems, program testing, team programming. Letter grading. Mr. Eggert, Mr. Millstein (F,Sp)

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: courses 32, 35L. Basic concepts in design and use of programming languages, including abstraction, modularity, control mechanisms, types, declarations, syntax, and semantics. Study of several different language paradigms, including functional, object-oriented, and logic programming. Letter grading. Mr. Eggert, Mr. Millstein (F,Sp)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 32, 35L, 131, 181. Compiler structure: lexical and syntactic analysis; semantic analysis and code generation; theory of parallel processing. Letter grading. Mr. Cong (F,Sp)

133. Parallel and Distributed Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 111 (may be taken concurrently), 131. Distributed memory and
shared memory parallel architectures; asynchronous parallel languages: MPI, Masie; primitives for parallel computation of parallel algorithms, communication, and/or parallelism in computer programs; computer-programming interfaces and implementation (including parallel and distributed computing); application of parallel algorithms to solve hard problems (such as fast Fourier transforms and matrix multiplication). 

161. Fundamentals of Artificial Intelligence. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 174A. Introduction to fundamental problem solving and knowl - edge representation paradigms of artificial intelligence. Introduction to Lisp with regular programming assignments. Major and problem reduction methods: brute-force, heuristics, search, planning, backtracking, and heuristics; expert systems and/or connectionist systems. Game playing, sentence understanding, speech understanding, image understanding, and/or robotics. Letter grading. Mr. Terzopoulos (Sp)

180. Introduction to Algorithms and Complexity. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A and Mathematics 61 or 180. Designed for junior/see - nior Computer Science majors. Introduction to design and analysis of algorithms. Design techniques: divide-and-conquer, greedy method, dynamic programming, branch-and-bound, randomization of problems. Analysis of algorithms in terms of data structures and representations; complexity mea- sures; time, space, upper, lower bounds, asymptotic complexity; NP-completeness. Letter grading. Mr. Gafni (F,W,Sp)


183. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory and some exposure to computer systems. Introduction to cryptography, computer security, and basic con- cepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudoran- dom generators, pseudorandom functions and pro- dductor permutations, semantic security, public- key and private-key encryption, key-agreement, ho- momorphic encryption, private information retrieval and voting protocols, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commit- ment protocols, and two-party secure computation with static security. Letter grading. Mr. Ostrovsky (Not offered 2012-13)

M184. Introduction to Computational and Sys- tems Biology. (2) (Formerly numbered M186A.) (Same as Bioengineering M184 and Computational and Systems Biology M184.) Lecture, four hours; outside study, four hours. Requisites: course 31 (or Pro- gram in Computing 10A). Mathematics 31A, 31B. Survey course designed to introduce students to computational and systems modeling and compu- tation in biology and medicine, providing motivation, fla- vor, culture, and cutting-edge contributions in compu- tational sciences. Topics include: model building and formulation for modeling biological and engineering systems. Letter grading. Mr. DiStefano (F)

CM186. Computational Systems Biology: Mod- eling and Simulation of Biological Systems. (5) (Formerly numbered CM186B.) (Same as Bioengineering CM186 and Computational and Systems Bi- ology M186.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electro- nical Engineering 102. Dynamic biosystems modeling and simulation of systems composed of biologi- cal/biomedical processes and systems at multiple levels of organization. Control system, multicompart- mental, predator-prey, pharmacokinetic (PK), phar- macodynamic (PD), and/or communication modeling methods applied to life sciences problems at molecu- lar, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translational genomics and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exer- cises in class (E and P). Concurrently scheduled with course CM286. Letter grading. Mr. DiStefano (F)
Graduate Courses

201. Computer Science Seminar. (2) Seminar, four hours; outside study, two hours. Designed for graduate computer science students. Seminars on current research topics in computer science. May be repeated for credit. S/U grading.

202. Advanced Computer Science Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: completion of major field examination in computer science or permission of the instructor. Seminar in research topics in computer science research into theory of analysis and synthesis of, and applications of information processing systems. Each member completes one tutorial and one more original pieces of work in one specialized area. May be repeated for credit. Letter grading.

211. Network Protocol and Systems Software Design for Wireless and Mobile Internet. (4) Lecture, four hours; outside study, eight hours. Required: course 118. Designed for graduate students. In-depth study of network protocol and systems software design in area of wireless and mobile Internet. Topics include (1) networking fundamentals; design philosophy of TCP/IP, end-to-end arguments, and protocol design principles, (2) networking protocols: 802.11 MAC standard, packet scheduling, mobile IP, ad hoc routing, and wireless TCP, (3) mobile computing systems software: middleware, file system, services, and applications, and (4) topical studies: energy-efficient design, security, location management, and quality of service. Letter grading. Mr. Lu (F)

212A. Queueing Systems Theory. (4) Lecture, four hours; outside study, eight hours. Required: course 212A. Priority queueing. Applications to time-sharing scheduling algorithms: FB, Round Robin, Conservation Law, Bounds. Queueing networks: definitions; job flow balance; product form solutions — local balance; M/M/1; M/M/C; heavy traffic; performance measures; asymptotic behavior and bounds; approximate techniques diffusion — iterative techniques; applications. Letter grading. Mr. Kleinrock

212B. Queueing Applications: Scheduling Algorithms and Queueing Networks. (4) Lecture, four hours; outside study, eight hours. Required: course 212A. Priority queueing. Applications to time-sharing scheduling algorithms: FB, Round Robin, Conservation Law, Bounds. Queueing networks: definitions; job flow balance; product form solutions — local balance; M/M/1; M/M/C; heavy traffic; performance measures; asymptotic behavior and bounds; approximate techniques diffusion — iterative techniques; applications. Letter grading. Mr. Kleinrock

217A. Internet Architecture and Protocols. (4) Lecture, four hours; outside study, eight hours. Required: course 217A. Focus on core set of Internet protocols, including IP, core transport protocols, routing protocols, DNS, NTP, and security protocols such as DNPSEC, to understand principles behind design of these protocols, appreciate their design and implementation, and learn lessons from their operation. Letter grading. Ms. Zhang (W)

217B. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Required: course 217A. Designed for graduate students. Overview of Internet development history and fundamental principles underlying TCP/IP protocol design. Discussion of current Internet research topics, including latest research results in routing protocols, transport protocols, network measurements, network security protocols, and clean-slate approach to network architecture design. Fundamental issues in network protocol design and implementations. Letter grading. Ms. Zhang (Sp)


219. Current Topics in Computer System Modeling. (4) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer system modeling analysis in which instructor has developed special proficiency as consequences of research interests. Students report on selected topics. May be repeated for credit. Letter grading. Ms. Estrin, Mr. Liu (Sp)

CM221. Introduction to Bioinformatics. (4) (Same as Bioinformatics M260A, Chemistry CM260A, and Human Genetics CM221.) Lecture, four hours; discussion, two hours. Required: courses 32 or Program in Computing 10C with grade of C- or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 170A or 110A. Course CM221 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM121. S/U or letter grading.

CM222. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Bioinformatics M260B and Chemistry CM260B.) Lecture, four hours; discussion, two hours. Required: courses 32 or Program in Computing 10C with grade of C- or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 170A or 110A. Course CM221 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM221. Letter grading. Mr. Eskin (F)
problems using computational techniques from statistics and computer science. Concurrently scheduled with other CM courses.

229S. Seminar: Current Topics in Bioinformatics. (4) (Same as Human Genetics M229S.) Seminar, four hours; outside study, eight hours. Designed for graduate engineering students, as well as students from biological sciences and medical school. Preparation: C or C++ programming experience. Letter grading.

234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Introduction to theory and practice of formal methods for design and analysis of concurrent and embedded systems. Topics include techniques for checking logical properties of hardware and software systems. Topics include semantics of reactive systems, invariant verification, temporal logic model checking, theory of omega automata, state-space reduction techniques, compositional and hierarchical reasoning. Letter grading. Mr. Majumdar

235. Advanced Operating Systems. (4) Lecture, four hours. Preparation: C or C++ programming experience. Letter grading. Mr. Eskin

236. Computer Security. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 118, 181. Paradigms, models, and techniques for providing security and assurance in computer systems. Letter grading. Mr. Chu

240A. Databases and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131, 181. Logical models for data organization and retrieval. Topics include knowledge base management, knowledge-base maintenance, knowledge-base/database systems. Letter grading. Mr. Miller

240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131, 143, 181, 185. Selected topics. May be repeated for credit with consent of instructor. Letter grading.

241B. Pictorial and Multimedia Database Management. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/pictures, video, and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and multimedia projects; presentation on independent data sources. Letter grading.

244A. Distributed Database Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 215 and/or 240A. Intelligent directory design, transaction management, deadlock, strong and weak concurrency control, commit protocols, semantic query answering, multidatabase systems, fault recovery techniques, networks, partitioning, examples, trade-offs, and design experiences. Letter grading.

245A. Intelligent Information Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 112, 143, 180, 181. Design for graduate students. Scale of Web data requires novel algorithms and principles for their management and retrieval. Study of Web characteristics and new management techniques needed to build computer systems suitable for Web use. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh techniques, Web search ranking algorithms, and query processing techniques on independent data sources. Letter grading.

249. Current Topics in Data Structures. (2 to 12) Lecture, four hours; outside study, eight hours. Requisite: courses 112, 143, 180, 181. Review of current literature in area of computer science. Topics include high-performance systems, and intelligent planning and scheduling systems. Letter grading. Mr. Cho

251A. Advanced Computer Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 111. Design and implementation of high-performance systems, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW processors, branch prediction, speculative execution, software support for instruction-level parallelism, simulation-based performance analysis and evaluation, state-of-the-art design examples, introduction to parallel architectures. Letter grading.

251B. Parallel Computer Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. SIMD and MIMD systems, symmetric multiprocessors, distributed-shared-memory systems, messages-passing systems, multithreaded clusters, clusters, interconnection networks, host-network interfaces, switching element design, communication primitives, cache coherence, memory consistency models, synchronization primitives, state-of-the-art design examples. Letter grading.

252A. Arithmetic Algorithms and Processors. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Number systems: conventional, redundant, signed-digit residue. Types of algorithms, implementations. Complexity measures. Fast algorithms and implementations for two-operand addition, multipoperand addition, multiplication, divi-
286. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course M51A. Detailed study of various problems in testing and testable designs of VLSI systems, including fault modeling, fault simulation, testing for single stuck faults and multiple stuck faults, functional testing, design for testability, compression techniques, and built-in self-test. Letter grading.

Mr. Cong


Mr. Korf (Sp)

258A. Design of VLSI Circuits and Systems. (4) (Same as Electrical Engineering M216A.) Lecture, four hours; discussion, one hour; laboratory, four hours. Requisite: course M51A or Electrical Engineering M16, and Electrical Engineering 115A. Recommended: Electrical Engineering 115C. LSI/VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading.

Mr. Boyles (W)

258C. LSI in Computer System Design. (4) (Same as Electrical Engineering M216C.) Lecture, four hours; laboratory, two hours; outside study, four hours. Requisite: course M258A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading.

259A. Computer Memories and Memory Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Generic types of memory systems; control, access modes, hierarchies, and al- location strategies. Static memories, dynamic memories, and semiconductor memories. Letter grading.

Mr. Chu

259B. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requisite: courses M258A, 258F. Detailed study of design of VLSI circuits, including logic partitioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven layout. Discussion of number of important design par- titioning optimization techniques, such as network flows, Steiner trees, simulated annealing, and genetic algo- rithms. Letter grading. (Same as Electrical Engineering M216C.) Lecture, four hours; outside study, eight hours. Requisite: courses M51A, 180. Detailed study of various problems in logic-level synthesis of VLSI digital systems, including two-level Boolean network optimization; multi-level Boolean network optimization; tech- nology mapping for standard cell designs and field-programmable gate array (FPGA) designs; retiming for sequential circuits; and applications of binary de- cision diagrams (BDDs). Letter grading.

Mr. Cong

259F. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Review of basic concepts and tools for solving physical design problems of VLSI circuits, including logic par- titioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven layout. Discussion of number of important design par- titioning optimization techniques, such as network flows, Steiner trees, simulated annealing, and genetic algo- rithms. Letter grading.

Mr. Pearl

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: courses M51A, 180. Detailed study of various problems in logic-level synthesis of VLSI digital systems, including two-level Boolean network optimization; multi-level Boolean network optimization; tech- nology mapping for standard cell designs and field-programmable gate array (FPGA) designs; retiming for sequential circuits; and applications of binary de- cision diagrams (BDDs). Letter grading.

Mr. Cong

259M. Machine Learning Theory. (4) Lecture, four hours. Preparation: basic knowledge of probability and ability to read and write mathematical proofs. Theoretical foundations underlying common machine learning algorithms. Topics include introduction to PAC learning model, uniform convergence theory, VC dimension, online learning, no-regret learning, online convex optimization, ensemble methods and boost- ing, StAB, and connections to games. Letter grading.

Ms. Vaughan


Mr. Korf (Sp)

262A. Reasoning with Partial Beliefs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112 or Electrical Engineering 131A. Review of several formalisms for representing and managing uncertainty in reasoning systems; presentation of comprehensive description of Bayesian inference us- ing belief networks representation. Letter grading.

Mr. Darwiche (W)


Mr. Pearl


Mr. Pearl


Mr. Pearl

263A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Introduction to natural language processing (NLP), with emphasis on semantics. Pre- sentation of process models for variety of tasks, in- cluding question answering, paraphrasing, machine translation, word-sense disambiguation, narrative and editorial comprehension. Examination of both symbolic and statistical approaches to natural language processing and acquisition. Letter grading. (Same as Electrical Engineering M216C.) Lecture, four hours; outside study, eight hours. Requisite: course 161. Introduction to theory and practice of automated reasoning using propositional and first-order logic. Topics include syntax and semantics of formal logic; algorithms for logical reasoning, including satisfi- ability and entailment; syntactic and semantic restrictions on knowledge bases; effect of these restrictions on expressiveness, compactness, and computational tractability; applications of automated reasoning to di- agnosis, planning, design, formal verification, and re- liability analysis. Letter grading. (Same as Electrical Engineering M216C.) Lecture, four hours; outside study, eight hours. Requisite: courses 263A, 264A. Introduction to machine learning. Learning by analogy, inductive learning, modeling creativity, learn- ing by experience, role of memory in organiza- tion in learning. Examination of BACON, AM, Eurisko, HACKER, teachable production systems. Failure- driven learning. Letter grading.

Mr. Pearl

264A. Automated Reasoning: Theory and Appli- cations. (4) Lecture, four hours; outside study, four hours. Requisite: course 130 or 131 or 161. Introduction to theory and practice of automated reasoning using propositional and first-order logic. Topics include syntax and semantics of formal logic; algorithms for logical reasoning, including satisfi- ability and entailment; syntactic and semantic restrictions on knowledge bases; effect of these restrictions on expressiveness, compactness, and computational tractability; applications of automated reasoning to di- agnosis, planning, design, formal verification, and re- liability analysis. Letter grading. (Same as Electrical Engineering M216C.) Lecture, four hours; outside study, eight hours. Requisite: courses 263A, 264A. Introduction to machine learning. Learning by analogy, inductive learning, modeling creativity, learn- ing by experience, role of memory in organiza- tion in learning. Examination of BACON, AM, Eurisko, HACKER, teachable production systems. Failure- driven learning. Letter grading.

Mr. Pearl

266A. Statistical Modeling and Learning in Vi- sion and Science. (4) (Same as Statistics M242.) Lecture, three hours. Preparation: basic statistics, lin- ear algebra (matrix analysis), computer vision. Com- puter vision and pattern recognition. Study of four types of statistical models for modeling visual pat- terns: descriptive, causal Markov, generative (hidden Markov), and discriminative. Comparison of prin- ciples and algorithms for these models; presentation of

M266B. Statistical Computing and Inference in Vision and Image Science. (4) (Same as Statistics M232B.) Lecture, three hours. Preparation: basic statistics, linear algebra (matrix analysis), computer vision. Introduction to broad range of algorithms with statistical inference and learning that could be used in vision, pattern recognition, speech, bioinformatics, data mining. Topics include Markov chain Monte Carlo computing, sequential Monte Carlo methods, belief propagation, partial differential equations, S/U or letter grading.

267A. Neural Models. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Review of major neurophysiological milestones in understanding brain architecture and processes. Focus on brain theories that are important for modern computer science and, in particular, on models of sensory perception, sensory-motor coordination, and cerebellar and cerebral structure and function. Students required to prepare papers analyzing research in one area of interest. Letter grading.

Mr. Vital

267B. Artificial Neural Systems and Connectionist Computing. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Analysis of connectionism, computing paradigms and underlying models of biological and physical processes. Examination of past and current implementations of artificial neural networks along with their applications to associative knowledge processing, generalization, and pattern recognition including vision and audition, and adaptive robot control. Students required to prepare papers analyzing research in one area of interest. Letter grading.

Mr. Vital


Mr. Soatto (F)

268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for students undertaking research thesis. Discussion of advanced topics and current research in computational neuroscience. Neural net computation as paradigm for parallel and concurrent computation in application to problems of perception, vision, multisensory integration, and robotics. S/U or letter grading.

Mr. Soatto, Ms. Vaughan (F)

269. Seminar: Current Topics in Artificial Intelligence. (4) Seminar, to be arranged. Review of current literature and research practicum in area of artificial intelligence in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

M270A. Computer Methodology: Complex Numerical Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 103 or Mathematics 151B or comparable experience with numerical computing. Designed for graduate computer science and engineering students. Principles of computer treatment of selected numerical problems in algebraic and differential systems, transforms and spectra, data acquisition and reduction; emphasis on concepts pertinent to modeling and simulation and applicability of contemporary developments in numerical software. Computer exercises. Letter grading.

Mr. Carlyle


271C. Seminar: Advanced Simulation Methods. (2) Seminar, two hours; outside study, six hours. Requisite: course 271A. Discussion of advanced topics in simulation of systems characterized by ordinary and partial differential equations. Topics include (among others) simulation languages, dataflow machines, array processors, and advanced mathematical modeling techniques. Topics vary each term. May be repeated for credit. S/U grading.

272. Advanced Discrete Event Simulation and Modeling Techniques. (4) Lecture, four hours; outside study, eight hours. In-depth study in discrete event simulation techniques, including building valid and credible simulation models, output analysis of systems, comparisons of alternative system configurations. Variance reduction techniques, simulation models of computer systems and manufacturing systems. Letter grading.

273A. Digital Processing of Engineering and Statistical Data. (4) Lecture, four hours; outside study, eight hours. Emphasis on design and engineering and statistical data. Emphasis on design and engineering and statistical data. Analysis of major connectionist computing paradigms and applications to associative knowledge processing, generalization and inference. Examination of past and current implementations of artificial neural networks along with their applications to associative knowledge processing, generalization, and pattern recognition including vision and audition, and adaptive robot control. Students required to prepare papers analyzing research in one area of interest. Letter grading.

Mr. Terzopoulos (Sp)

274C. Machine Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particles and systems, and motor control. Concurrently scheduled with course C174C. Letter grading.

Mr. Terzopoulos (Sp)

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161. Investigation of important role that concepts from artificial life, emerging discipline that spans computational and biological sciences, can play in construction of advanced computer graphics and understanding of visual realism, animation, interactive games, active vision, visual sensor networks, medical image analysis, etc. Focus on comprehensive models that can realistically emulate variety of living things (plants and animals) from lower animals to humans. Exposure to effective computational modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control, behavioral animation, reinforcement and neural-network simulation, cognitive modeling, artificial animals and humans, human facial animation, and artificial evolution. Letter grading.

Mr. Terzopoulos

M276A. Pattern Recognition and Machine Learning. (4) (Same as Statistics C231L.) Lecture, three hours. Recommended for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are used in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering, complexity (VC-dimension), MDL, AIC/MDA, TCA, MDS, SVM, boosting. S/U or letter grading.

Mr. Zhu

276B. Structured Computer Vision. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Methods for computer processing of image data. Systems, concepts, and algorithms for image analysis, radiologic and robotic applications. Letter grading.

276C. Speech and Language Communication in Artificial Intelligence. (4) Lecture, eight hours. Requisite: course M276A or 276B. Topics in human-computer communication: interaction with pictorial information systems, sound and symbol generation by humans and machines, semantics of data, systems for speech recognition and understanding. Use of speech and text for computer input and output in applications. Letter grading.

M278. Probabilistic Models of Cognition. (4) (Same as Statistics M239.) Seminar, three hours; discussion, one hour. Requisites: course 180, Mathematics 33A, Statistics 100B. Modeling aspects of human cognition, designing artificial intelligence systems. Introduction to conceptual foundations and basic mathematical and computational techniques. Topics illustrated on different aspects of cognition. S/U or letter grading.

279. Current Topics in Computer Science: Methodologies. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer science methodology in which instructor has developed special proficiency. May be repeated for credit with topic change. Letter grading.

280A-280ZZ. Algorithms. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections from design, analysis, optimization, and implementation of algorithms; computational complexity; general theory of algorithms; algorithms for particular application areas. Subtitles of some current sections: Principles of Design and Analysis (280A); Distributed Algorithms (280B); Graphs Algorithms. May be repeated for credit with consent of instructor and topic change. Letter grading.

280AP. Approximation Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Background in discrete mathematics helpful. Theoretically sound techniques for dealing with NP-Hard problems. Inability to solve these problems efficiently means algorithmic techniques are based on approximation methods—finding solutions that are the best possible in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include probabilistic, integer program rounding, greedy algorithms, and local search. Letter grading.

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or compatible background. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets, closure properties, machine characterization, nondeterminism, decidability, unsolvable problems, “easy” and “hard” problems, PTIME/ NPTIME. Letter grading.

Mr. Ostrovsky (W)

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Recommended prerequisite: course 181. Finite-state machines, transducers, and their generalizations; regular expressions, transduction expressions, realizability, decomposition synthesis, and structural equivalences; topics in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system modeling and simulation. Letter grading.

Mr. Carlyle

M282A. Cryptography. (4) (Same as Mathematics M209A.) Lecture, four hours; outside study, eight hours. Introduction to theory of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hardness core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic
security, public-key and private-key encryption, se-
cret-sharing, message authentication, digital signa-
tures, interactive proofs, zero-knowledge, computa-
tion-resistant hash functions, commitment protocols, key-agreement, contract signing, and two-party se-
cure computation with static security. Letter grading.

Mr. Ostrovsky

M282B. Cryptographic Protocols, (4) (Same as Mathematics M206B.) Lecture, four hours; outside study, eight hours. Requisite: course M282A. Consider-
eration of advanced cryptographic protocol design and analysis of noninteractive zero-knowledge proofs; zero-knowledge arguments; concurrent and non-black-box zero-knowledge; IP=PSPACE proof, stronger notions of security for public-key systems, choosing chosen-plaintext secure; secure multiparty computation; dealing with dynamic adversary; nonmalleability and composability of secure protocols; software protection; threshold cryptography; identity-based cryptography; private in-
formation retrieval; protection against man-in-middle attacks; voting protocols; identification protocols; di-
gital cash schemes; lower bounds on use of crypto-
graphic primitives, software obfuscation. May be re-
peated for credit with topic change. Letter grading.

Mr. Ostrovsky

M283A-M283B. Topics in Applied Number Theory. (4-4) (Same as Mathematics M208A-M208B.) Lecture, three hours; outside study, including comput-
gers, coding theory, and number theory. Elliptic curves, Coding theory: public key and discrete log cryptosystems. Attacks on cryptosys-
tems. Primality testing and factorization meth-
ods. Elliptic curves. Topics from coding theory in coding the-

M284A-284ZZ. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 181. Additional requisites for each offering announced in advance by department. Selections from families of formal languages, gram-
mars, recursion, pushdown automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Subsets of current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284P). May be repeated for credit with consent of instructor and topic change. Letter grading.

Mr. Sahai (Sp)

CM286. Computational Systems Biology: Model-
ing and Simulation of Biological Systems. (5) (Formerly numbered CM286B.) (Same as Bioengi-
eering CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electrical Engineering 102. Dynamic systems modeling and computer simulation methods for studying biological/biomedical processes and sys-
tems at multiple levels of organization. Control sys-
tem, multiprocessor, predator-prey, pharmacoki-
etic (PK), pharmacodynamic (PD), and other struc-
tural modeling methods applied to life sciences problems at molecular, cellular (biochemical path-
ways/networks), organ, and organismic levels. Basic theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathe-
matics models and implementing them for simulation and analysis of numerical simulation algo-
rithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading. Mr. DiStefano (F)

CM287. Introduction to Computational and Systems Biology. (2 to 4) (Formerly numbered CM286C.) (Same as Bioengineering CM288.) Lecture, one hour; discus-
sion, two hours; laboratory, one hour; outside study, eight hours. Requisite: course CM186. Closely inter-
ed, interactive, and real research experience in active quantitative systems biology research laboratory. Di-
rection of instructors to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critiques of original presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effec-
tive research reporting, both oral and written. Concur-
rently scheduled with course CM187. Letter grading. Mr. DiStefano (Sp)

287A. Theory of Program Structure. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Models of computer programs and their syntax and semantics; emphasis on programs and recursion schemes; equivalence, optimization, cor-
rectness, and translatability of programs; expressive power of program constructs and data structures; se-
lected current topics. Letter grading. Ms. Greibach

288S. Seminar: Theoretical Computer Science, (2) Seminar, two hours; outside study, six hours. Requi-
sites: courses 280A, 281A. Intended for students undertaking thesis research. Discussion of advanced topics and current research in such areas as algo-
rithms and complexity models for parallel and concur-
rent computation, and formal language and automata theory. May be repeated for credit. S/U grading.

Ms. Greibach

289A-289ZZ. Current Topics in Computer Theory. (2 to 12 each) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer theory in which instructor has developed special proficiency as consequence of research inter-
ests. Students report on selected topics. Letter grading.

289CO. Complexity Theory. (4) Lecture, four hours; outside study, eight hours. Diagonalization, poly-
nomial-time hierarchy, completeness and de-
randomization, circuit complexity, attempts and limita-
tions to proving P does not equal NP, average-case complexity, one-way functions, hardness amplifica-
tion. Problem sets and presentation of original and original research related to course topics. Letter grading.

Mr. Sahai (F)

289OA. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. In-
troduction to decision making under uncertainty. Approaches to solutions. Individual M.S.- and Ph.D.
level project training. Letter grading. Mr. Korf

289RA. Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomized algorithms, such as probabilistic analysis, Markov chains, random walks, and probabilistic method. Applications to randomized algorithms in data structures, graph theory, computa-
tional geometry, number theory, and parallel and dis-
tributed systems. Letter grading.

289AR. Directed Individual or Tutorial Studies. (1 to 6) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for M.S. comprehensive examination. May be repeated for credit. S/U grading.

Mr. Cardenas

289D-497E. Field Projects in Computer Science. (4-4) Fieldwork, to be arranged. Students are divided into teams led by instructor; each team is assigned one or more of several companies. Students may in-
vestigate as candidate for possible computerization, submitting team report of their findings and recom-
mendations. Repeatable for credit. S/U grading.

Mr. Korf

297A. Preparation for M.S. Comprehensive Exam-
nation. (2 to 12) Tutorial, to be arranged. Limited to graduate computer science students. Preparation and preparation for M.S. comprehensive examination.

297B. Preparation for Ph.D. Preliminary Examina-
tions. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for Ph.D. preliminary examinations.

297C. Preparation for Ph.D. Oral Qualifying Exam-
nation. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for oral qualifying examination, including preliminary re-
598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate computer science students. Supervised independent research for M.S. candidates, including thesis prospectus. S/U grading.

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. S/U grading.

Electrical Engineering

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Professors
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Abeer A.H. Alwan, Ph.D.
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Jack W. Judy, Ph.D.
William J. Kaiser, Ph.D.
Alan J. Laub, Ph.D.
Kuo-Nan Liou, Ph.D.
Jia-Ming Liu, Ph.D.
Warren B. Mori, Ph.D.
Stanley J. Osher, Ph.D.
C. Kumar N. Patel, Ph.D.
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Yahya Rahmat-Samii, Ph.D., (Northrop Grumman Professor of Electrical Engineering/ Electromagnetics)
Behzad Razavi, Ph.D.
Vvani P. Roychowdhury, Ph.D.
Izhak Rubin, Ph.D.
Henry Samueli, Ph.D.
Ali H. Sayed, Ph.D.
Stefano Soatto, Ph.D.
Jason L. Speyer, Ph.D.
Mani B. Srivastava, Ph.D.
Oscar M. Stafsudd, Ph.D.
Pablo Tabuada, Ph.D.
King-Ning Tu, Ph.D.
Lien Lie Vandenbergh, Ph.D.
Michaela van der Schaar, Ph.D.
John D. Villasenor, Ph.D.
Kang L. Wang, Ph.D. (Raytheon Company Professor of Electrical Engineering)
Richard D. Wesel, Ph.D., Associate Dean
Alan N. Willson, Jr., Ph.D. (Charles P. Reame Endowed Professor of Electrical Engineering)

Jason C.S. Woo, Ph.D.
C.-K. Ken Yang, Ph.D.
Kung Yao, Ph.D.

Professors Emeriti
Frederick G. Allen, Ph.D.
Francis F. Chen, Ph.D.
Harold R. Fettermen, Ph.D.
Stephen E. Jacobsen, Ph.D.
Rajeev Jain, Ph.D.
Nhan N. Levan, Ph.D.
Dee-Son Pan, Ph.D.
Frederick W. Schott, Ph.D.
Gabor C. Temes, Ph.D.
Chand R. Viswanathan, Ph.D.
Paul K.C. Wang, Ph.D.
Donald M. Wiberg, Ph.D.
Jack Willis, B.Sc.

Associate Professors
Mark H. Hansen, Ph.D.
Dejan Markovic, Ph.D.
Aydogan Ozcan, Ph.D.
Sudhakar Patampati, Ph.D.
Yuanxun Ethan Wang, Ph.D.

Assistant Professors
Daniela Cabric, Ph.D.
Robert N. Candler, Ph.D.
Chi On Chui, Ph.D.
Lara Dolecek, Ph.D.
Puneet Gupta, Ph.D.
Benjamin S. Williams, Ph.D.

Adjunct Professors
Ezio Biglieri, Ph.D.
Mary Estahgian-Wilner, Ph.D.
Michael P. Fitz, Ph.D.
Asad M. Madni, Ph.D.
Ingrid M. Verbauwhede, Ph.D.
Eli Yablonovitch, Ph.D.

Adjunct Assistant Professor
Jin-Hyung Lee, Ph.D.

Scope and Objectives
The Department of Electrical Engineering fosters a dynamic academic environment that is committed to a tradition of excellence in teaching, research, and service and has state-of-the-art research programs and facilities in a variety of fields. Departmental faculty members are engaged in research efforts across several disciplines in order to serve the needs of industry, government, society, and the scientific community. Interactions with other disciplines are strong. Faculty members regularly conduct collaborative research projects with colleagues in the Geffen School of Medicine, Graduate School of Education and Information Studies, School of Theater, Film, and Television, and College of Letters and Science.

There are three primary research areas in the department: circuits and embedded systems, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunication, control systems, electromagnet-
ics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

The program grants one undergraduate degree (Bachelor of Science in Electrical Engineering) and two graduate degrees (Master of Science and Doctor of Philosophy in Electrical Engineering). The graduate program provides students with an opportunity to pursue advanced coursework, in-depth training, and research investigations in several fields.

Department Mission
The education and research activities in the Electrical Engineering Department are aligned with its mission statement. In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental knowledge of electrical engineering who can provide leadership and service to California, the nation, and the world, (2) pursue creative research and new technologies in electrical engineering and across disciplines in order to serve the needs of industry, government, society, and the scientific community, (3) develop partnerships with industrial and government agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

Undergraduate Program Objectives

The electrical engineering curriculum provides an excellent background for either graduate study or employment. Undergraduate education in the department provides students with (1) fundamental knowledge in mathematics, physical sciences, and electrical engineering, (2) the opportunity to specialize in specific areas of interest or career aspiration, (3) intensive training in problem solving, laboratory skills, and design skills, and (4) a well-rounded education that includes communication skills, the ability to function well on a team, an appreciation for ethical behavior, and the ability to engage in lifelong learning. This education is meant to prepare students to thrive and to lead. It also prepares them to achieve the following two program educational objectives: (1) that graduates of the program have successful technical or professional careers and (2) that graduates of the program continue to learn and to adapt in a world of constantly evolving technology.

Undergraduate Study
The Electrical Engineering major is a designated capstone major. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained in previous mathematics, science, and engineering coursework. Within a multidisciplinary team structure, students identify, formulate, and solve engineering problems and present their projects to the class.

Electrical Engineering B.S.
Capstone Major
The undergraduate curriculum allows Electrical Engineering majors to specialize in one of three emphasis areas or options. The three options are structured as an electrical engineering degree, and the only degree offered to undergraduate students by the department is the Bachelor of Science degree in Electrical Engineering.

No distinction is made among the three options: (1) electrical engineering (EE) option is the regular option that provides students with preparation in electrical engineering with a range of required and elective courses across several disciplines; (2) computer engineering (CE) option provides students with preparation in embedded systems and software and hardware issues. Students replace some of the senior courses in the regular EE option with computer engineering-oriented courses or computer science courses; and (3) biomedical engineering (BE) option provides students with exposure to additional chemistry and life sciences courses and helps them meet most of the premedical preparation requirements so that they are prepared for careers in bioengineering, medicine, or electrical engineering.

Electrical Engineering Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical Engineering 1, 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL.

The Major
Required: Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115AL, 121B, 131A, 132A, 141, 161, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from one of the following pathways:

Antennas and Microwaves: Three major field elective courses from Electrical Engineering 162A, 163A, and either 163B or 163C; one capstone design course from 164D or 184DA/184DB (count as one course); and one laboratory course from 164L (or by petition from 194 or 199).

Integrated Circuits: Three major field elective courses from Electrical Engineering 115B, 115C, and either 132B or 163A; one capstone design course from 115D or 184DA/184DB (count as one course); and one laboratory course from 115BL (or by petition from 194 or 199).

Microelectromechanical (MEMS) Systems: Three major field elective courses from Electrical Engineering 115B or 123A or 124, 128 or 163A or 173, and CM150; one capstone design course from 129D; and one laboratory course from 122L or CM150L (or by petition from 194 or 199).

Photonics and Plasma Electronics: Three major field elective courses from Electrical Engineering 172, 173, and either 174 or 175 or M185; one capstone design course from 173D; and one laboratory course from 170L (or by petition from 194 or 199).

Signals and Systems: Three major field elective courses from Electrical Engineering 114, 115B, 131B, 132B, 136, 142, 162A; one capstone design course from 113D, 173D, 180D, 181D, or 184DA/184DB (count as one course); and one laboratory course from 115BL or M116L or M171L (or by petition from 194 or 199).

Solid State: Three major field elective courses from Electrical Engineering 123A, 123B, and either 124 or 128; one capstone design course from 129D; and one laboratory course from 122L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.
Biomedical Engineering Option

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL; Computer Science 31; Electrical Engineering 1, 2, 3, 10, M16 (or Computer Science M51A); Life Sciences 2, 3, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL.

The Major

Required: Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115AL, 131A, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 units) selected from the biomedical engineering pathway as follows: three major field elective courses from Bioengineering CM118, Electrical Engineering 114, 132A, 141, and either Electrical Engineering 176 or Mechanical and Aerospace Engineering 105A; one capstone design course from Electrical Engineering 113D or 180D; and one laboratory course from Bioengineering CM187 or Electrical Engineering M171L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Computer Engineering Option

Preparation for the Major

Required: Chemistry and Biochemistry 20A; Computer Science 31, 32, 33, 35L; Electrical Engineering 1, 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL.

The Major

Required: Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115C, M116C (or Computer Science M151B), 131A, 132B or Computer Science 118, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from the computer engineering pathway as follows: three major field elective courses from Computer Science 111, M117 (or Electrical Engineering 132A), and either 131 or 132 or 180; one capstone design course from Electrical Engineering 113D, 180D, 181D, or 184DA/184DB (count as one course); and one laboratory course from Electrical Engineering M116L (or by petition from 194 or 199). For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission see Graduate Programs, page 23. The following introductory information is based on the 2012-13 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

The Department of Electrical Engineering offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Electrical Engineering.

Electrical Engineering M.S.

Areas of Study

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. Students must select a number of formal graduate courses to serve as their major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) two Electrical Engineering 598 courses involving work on the M.S. thesis, (e) no other 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, and (f) an M.S. thesis completed under the direction of the faculty adviser to a standard that is approved by a committee comprised of three faculty members. The thesis research must be conducted concurrently with the coursework.

4. Thesis Option. Students selecting the thesis option must complete at least the following requirements: (a) five formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) two Electrical Engineering 598 courses involving work on the M.S. thesis, (e) no other 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, and (f) an M.S. thesis completed under the direction of the faculty adviser to a standard that is approved by a committee comprised of three faculty members. The thesis research must be conducted concurrently with the coursework.

5. Non-Thesis Option. Students selecting the non-thesis option must complete at least the following requirements: (a) six formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) Electrical Engineering 299 to serve as the M.S. comprehensive examination, which is evaluated by a committee of three faculty members appointed by the department. In case of failure, students may be reexamined only once with consent the departmental graduate adviser, and (e) no 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements.

6. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed above for the
thesis (seven courses) and non-thesis (eight courses) options. The selection of the major and minor sequences of courses must be from different established tracks, or approved ad hoc tracks, or combinations thereof. The selected courses must be approved by the faculty adviser.

7. For the thesis option at least four, and for the non-thesis option five, of the formal graduate courses used to satisfy the M.S. program requirements listed above must be in the Electrical Engineering Department.

8. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses.

9. At most one upper division undergraduate course is allowed to replace one of the formal graduate courses covering the major and minor fields of study provided that (a) the undergraduate course is not required of undergraduate students in the Electrical Engineering Department and (b) the undergraduate course is approved by the faculty adviser.

10. A track is a coherent set of courses in some general field of study. The department suggests lists of established tracks as a means to assist students in selecting their courses. Students are not required to adhere to the suggested courses in any specific track.

Circuits and Embedded Systems Area Tracks

1. Embedded Computing Track. Courses deal with the engineering of computer systems as may be applied to embedded devices used for communications, multimedia, or other such restricted purposes. Courses include Computer Science 251A, Electrical Engineering 201A, 201C, M202A, M202B, 213A, M216A.

2. Integrated Circuits Track. Courses deal with the analysis and design of analog and digital integrated circuits; architecture and integrated circuit implementations of large-scale digital processors for communications and signal processing; hardware-software codesign; and computer-aided design methodologies. Courses include Computer Science 251A, 252A, Electrical Engineering 213A, 215A through 215E, M216A, 221A, 221B.

Physical and Wave Electronics Area Tracks

1. Electromagnetics Track. Courses deal with electromagnetic theory; propagation and scattering; antenna theory and design; microwave and millimeter wave circuits; printed circuit antennas; integrated and fiber optics; microwave-optical interaction, antenna measurement, and diagnostics; numerical and asymptotic techniques; satellite and personal communication antennas; periodic structures; genetic algorithms; and optimization techniques. Courses include Electrical Engineering 211C, 260A, 260B, 261, 262, 263, 266, 270.

3. **Solid-State and Microelectromechanical Systems (MEMS) Devices Track.**
Courses deal with solid-state physical electronics, semiconductor device physics and design, and microelectromechanical systems (MEMS) design and fabrication. Courses include Electrical Engineering 221A, 221B, 221C, 222, 223, 225, CM250A, M250B, Mechanical and Aerospace Engineering 281, 284, C287L

### Signals and Systems Area Tracks

1. **Communications Systems Track.**
Courses deal with communication and telecommunication principles and engineering applications; channel and source coding; spread spectrum communication; cryptography; estimation and detection; algorithms and processing in communication and radar; satellite communication systems; stochastic modeling in telecommunication engineering; mobile radio engineering; and telecommunication switching, queuing system, communication networks, local-area, metropolitan-area, and wide-area computer communication networks. Courses include Electrical Engineering 205A, 210A, 230A through 230D, 231A, 231E, 232A through 232E, 233, 238, 241A

2. **Control Systems and Optimization Track.**
Courses deal with state-space theory of linear systems; optimal control of deterministic linear and nonlinear systems; stochastic control; Kalman filtering; stability theory of linear and nonlinear feedback control systems; computer-aided design of control systems; optimization theory, including linear and nonlinear programming, convex optimization and engineering applications; numerical methods; nonconvex programming; associated network flow and graph problems; renewal theory; Markov chains; stochastic dynamic programming; and queuing theory. Courses include Electrical Engineering 205A, 208A, M208B, M208C, 210B, 236A, 236B, 236C, M237, M240A, 240B, M240C, 241A, 241C, M242A, 243

3. **Signal Processing Track.**

### Ad Hoc Tracks

In consultation with their faculty advisers, students may petition for an ad hoc track tailored to their professional objectives. This may comprise graduate courses from established tracks, from across areas, and even from outside electrical engineering. The petition must justify how the selection of courses in the ad hoc track forms a coherent set of courses, and how the proposed ad hoc track serves the professional objectives. The petition must be approved by the faculty adviser and the departmental graduate adviser.

### Comprehensive Examination Plan

The M.S. comprehensive examination requirement is satisfied either (1) by solving a comprehensive examination problem in the final project, or equivalent, of every formal graduate electrical engineering course taken. A grade-point average of at least 3.0 in the comprehensive examination problems is required for graduation. The M.S. individual study program is administered by the academic adviser, the director of the area to which the students belong, and the vice chair of Graduate Affairs or (2) through completion of an individual study course (Electrical Engineering 289) under the direction of a faculty member. Students are assigned a topic of individual study by the faculty member. The study culminates with a written report and an oral presentation. The M.S. individual study program is administered by the faculty member directing the course, the director of the area to which the students belong, and the vice chair of Graduate Affairs. Students who fail the examination may be reexamined once with consent of the vice chair of Graduate Affairs.

### Electrical Engineering Ph.D.

#### Areas of Study

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

#### Course Requirements

The selection of courses for the Ph.D. program is tailored to the professional objectives of the students and must meet the requirements stated below. The courses should be selected and approved in consultation with the faculty adviser. Departures from the stated requirements are considered only in exceptional cases and must be approved by the departmental graduate adviser. Normally, students take additional courses to acquire deeper and broader knowledge in preparation for the dissertation research.

The minimum requirements for the Ph.D. degree are as follows:

1. **Requisite.** M.S. degree in Electrical Engineering or a related field granted by UCLA or by an institution recognized by the UCLA Graduate Division.

2. All Ph.D. program requirements should be completed within five academic years from admission into the Ph.D. graduate program in the Henry Samueli School of Engineering and Applied Science.

3. Students must maintain a minimum cumulative grade-point average of 3.5 in the Ph.D. program.

4. Students must complete at least the following requirements: (a) four formal graduate courses selected in consultation with the faculty adviser, (b) Electrical Engineering 297, (c) one technical communications course such as Electrical Engineering 295, (d) no 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, (e) pass the Ph.D. preliminary examination which is administered by the department and takes place once every year. In case of failure, students may be reexamined only once with consent of the departmental graduate adviser, (f) pass the University Oral Qualifying Examination which is administered by the doctoral committee, (g) complete a Ph.D. dissertation under the direction of the faculty adviser, and (h) defend the Ph.D. dissertation in a public seminar with the doctoral committee.

5. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses. Formal graduate courses taken to meet the M.S. degree requirements may not be applied toward the Ph.D. course requirements.
6. At least two of the formal graduate courses must be in electrical engineering.

7. Within two academic years from admission into the Ph.D. program, all courses should be completed and the Ph.D. preliminary examination should be passed. It is strongly recommended that students take the Ph.D. preliminary examination during their first academic year in the program.

8. The University Oral Qualifying Examination must be taken when all required courses are complete, and within one year after passing the Ph.D. preliminary examination.

9. Students admitted originally to the M.S. program in the Electrical Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination.

10. Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus.

Written and Oral Qualifying Examinations

The written qualifying examination is known as the Ph.D. preliminary examination in the department. The purpose of the examination is to assess student competency in the discipline, knowledge of the fundamentals, and potential for independent research. Students admitted originally to the M.S. program in the Electrical Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination, which is held once every year. Students are examined independently by a group of faculty members in their general area of study. The examination by each faculty member typically includes both oral and written components, and students pass the entire Ph.D. preliminary examination and not in parts. Students who fail the examination may repeat it once only with consent of the departmental graduate adviser. The preliminary examination, together with the course requirements for the Ph.D. program, should be completed within two years from admission into the program.

After passing the written qualifying examination described above, students are ready to take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus.

Facilities and Programs

Computing Resources

Students and faculty have access to a modern networked computing environment that interconnects UNIX workstations as well as Windows and Linux PCs. These machines are provided by the Electrical Engineering Department; most of them operate in a client-server mode, but stand-alone configurations are supported as well. Furthermore, this network connects to mainframes and supercomputers provided by the Henry Samueli School of Engineering and Applied Science and the Office of Academic Computing, as well as off-campus supercomputers according to need.

The rapidly growing department-wide network comprises about 500 computers. These include about 200 workstations from Sun, HP, and SGI, and about 300 PCs, all connected to a 100 Mbit/s network with multiple parallel T3 lines running to individual research laboratories and computer rooms. The server functions are performed by several high-speed, high-capacity RAID servers from Network Appliance and IBM which serve user directories and software applications in a unified transparent fashion. All this computing power is distributed in research laboratories, computer classrooms, and open-access computer rooms.

Research Centers and Laboratories

Center for High-Frequency Electronics

The Center for High-Frequency Electronics has been established with support from several governmental agencies and contributions from local industries, beginning with a $10 million grant from Hewlett-Packard.

The first major goal of the center is to combine, in a synergistic manner, five areas of research. These include (1) solid-state millimeter wave devices, (2) millimeter systems for imaging and communications, (3) millimeter wave high-power sources (gyrotrons), (4) GaAs gigabit logic systems, and (5) VLSI and LSI based on new materials and structures. The center supports work in these areas by providing the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations in new electronic devices. Students, both graduate and under-graduate, receive training and instruction in a unique facility.

The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different independent fields. The Electrical Engineering Department, other departments within UCLA, and local universities (such as Caltech and USC) have begun to combine and correlate certain research programs as a result of the formation of the center.

Clean Energy Research Center–Los Angeles

The Clean Energy Research Center–Los Angeles (CERC-LA) was created by UCLA to tackle many of the grand challenges related to generation, transmission, storage, and management of energy. As many energy challenges are global in nature, this new center will engage the participation of a multidisciplinary group of researchers from many nations. The director of this new center is professor Lei He. CERC-LA leads a U.S.-China clean energy and climate change research consortium. CERC-LA, together with the China National Center for Climate Change Strategy and International Cooperation (NCSC), Peking University (PKU), and Fudan University, was selected by the U.S. Department of State and the China National Development and Reform Commission as a U.S.-China EcoPartner. CERC-LA plans to have satellite offices in other cities including Shanghai and Beijing.
Circuits Laboratories
The Circuits Laboratories are equipped for measurements on high-speed analog and digital circuits and are used for the experimental study of communication, signal processing, and instrumentation systems. A hybrid integrated circuit facility is available for rapid mounting, testing, and revision of miniature circuits. These include both discrete components and integrated circuit chips. The laboratory is available to advanced undergraduate and graduate students through faculty sponsorship on thesis topics, research grants, or special studies.

Electromagnetics Laboratories
The Electromagnetics Laboratories involve the disciplines of microwaves, millimeter waves, wireless electronics, and electromechanics. Students enrolled in microwave laboratory courses, such as Electrical Engineering 164D and 164L, special projects classes such as Electrical Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: (1) integrated microwave circuits and antennas, (2) integrated millimeter wave circuits and antennas, (3) numerical visualization of electromagnetic waves, (4) electromagnetic scattering and radar cross-section measurements, and (5) antenna near field and diagnostics measurements.

Nanoelectronics Research Facility
The state-of-the-art Nanoelectronics Research Facility for graduate research and teaching as well as the undergraduate microelectronics teaching laboratory are housed in an 8,500-square-foot class 100/1000 clean room with a full complement of utilities, including high purity deionized water, high purity nitrogen, and exhaust scrubbers. The NRF supports research on nanometer-scale fabrication and on the study of fundamental quantum size effects, as well as exploration of innovative nanometer-scale device concepts. The laboratory also supports many other schoolwide programs in device fabrication, such as MEMS and optoelectronics. For more information, see http://www.nanolab.ucla.edu.

Photonics and Optoelectronics Laboratories
In the Laser Laboratory students study the properties of lasers and gain an understanding of the application of this modern technology to optics, communication, and holography. The Photonics and Optoelectronics Laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrastark lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al2O3 lasers, ultraviolet and visible wavelength argon lasers, wavelength-tunable dye lasers, as well as gallium arsenide, helium-neon, excimer, and high-powered continuous and pulsed carbon dioxide laser systems. Also available are equipment and facilities for research on semiconductor lasers, fiber optics, nonlinear optics, and ultrashort laser pulses. Facilities for mirror polishing and coating and high-vacuum gas handling systems are also available. These laboratories are open to undergraduate and graduate students who have faculty sponsorship for their thesis projects or special studies.

Plasma Electronics Facilities
Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art table top terawatt (T3) 400fs laser system that can be operated in either a single or dual frequency mode for laser-plasma interaction studies. Diagnostic equipment includes a ruby laser scattering system, a streak camera, and optical spectrographs and multichannel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing. The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focusable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS; other equipment includes a theta-pinch plasma generator, an electron linac injector, and electron detectors and analyzers.

A second group of laboratories is dedicated to basic research in plasma sources for basic experiments, plasma processing, and plasma heating. There is also a large computing cluster called DAWSON 2 that is dedicated to the study of plasma-based acceleration, inertial fusion energy, and high energy density plasma science. DAWSON 2 consists of 96 HP L390 nodes each with 12 Intel X5660 CPUs and 48 GB of RAM, and 3 Nvidia M2070s GPUs and 18 GB of Global Memory (for a total of 1152 CPUs and 288 GPUs) connected by a non-blocking QDR Infiniband network with 160TB of parallel storage from Panasas. The system’s peak performance is approximately 300TF/150TF (single/double precision) and it has a measured lindack performance of 68.1TF (double precision). DAWSON 2 is housed within the UCLA Institute for Digital Research Engineering data center.

Solid-State Electronics Facilities
Solid-state electronics equipment and facilities include (1) a modern integrated semiconductor device processing laboratory, (2) complete new Si and III-V compound molecular beam epitaxy systems, (3) CAD and mask-making facilities, (4) lasers for beam crystallization study, (5) thin film and characterization equipment, (6) deep-level transient spectroscopy instruments, (7) computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, (8) low-temperature facilities for material and device physics studies in cryogenic temperatures, (9) optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, (10) characterization equipment for high-speed devices, including (11) high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

Multidisciplinary Research Facilities
The department is also associated with several multidisciplinary research centers including:

- California NanoSystems Institute (CNSI)
- Center for Embedded Networked Sensing (CENS)
- Center for High-Frequency Electronics (CHFE)
- Center for Nanoscience Innovation for Defense (CNID)
- Functional Engineered Nano Architectonics Focus Center (FENA)
- Plasma Science and Technology Institute
- UCLA Wireless Health Institute
- Western Institute for Nanoelectronics (WIN)

Faculty Groups and Laboratories
Department faculty members also lead a broad range of research groups and labora-
Electrical Engineering

- Actuated Sensing and Coordinated Embedded Networked Technologies (ASCENT) Laboratory
- Adaptive Systems Laboratory (Sayed)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomous Intelligent Networked Systems (Rubin)
- BioPhotonics Laboratory (Ozcan)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Razavi)
- Complex Networks Group (Roychowdhury)
- Cyber-Physical Systems Laboratory (Tabuada)
- Device Research Laboratory (K. Wang)
- Digital Microwave Laboratory (E. Wang)
- Energy and Electronic Design Automation Laboratory (He)
- Flutter Systems Research Laboratory (Balakrishnan)
- High-Performance Mixed Mode Circuit Design Group (Yang)
- High-Speed Electronics Laboratory (Chang)
- Image Communications Laboratory (Villasenor)
- Information Theory and Systems Laboratory (Diggavi)
- Integrated Circuits and Systems Laboratory (Abidi)
- Laser-Plasma Group (Judy)
- Microfabrication Laboratory (Judy)
- Microsystems Research Laboratory (Judy)
- Microwave Electronics Laboratory (Itoh)
- Millimeter Wave and Optoelectronics Laboratory (Fetterman)
- Nanoelectronics Research Center (Candler, Franz)
- Nanooptoelectronics and Nanostructures Laboratory (Chui)
- Nanosystems Computer-Aided Design Laboratory (Gupta)
- Networked and Embedded Systems Laboratory (Srivastava)
- Neuroengineering Research Laboratory (Judy)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonovich)
- Proactive Medianet Laboratory (van der Schaar)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Electronics Laboratory (Stafsudd)
- Sensors and Technology Laboratory (Candler)
- Speech Processing and Auditory Perception Laboratory (Alwan)
- Terahertz Devices and Intersubband Nanostructures Group (Williams)
- Wireless Integrated Systems Research Group (Daneshrad)

Faculty Areas of Thesis Guidance

Professors

Asad A. Abidi, Ph.D. (UC Berkeley, 1981)
High-performance analog electronics, device modeling

Abbe A. Alwan, Ph.D. (MIT, 1992)
Speech processing, acoustic properties of speech sounds with applications to speech synthesis, recognition by machine and coding, hearing-aid design, and digital signal processing

Katsushi Aniaika, Ph.D. (U. Toyo, Japan, 1985)
High energy and astro-particle experiments

A.V. Balakrishnan, Ph.D. (USC, 1954)
Control and communications, flight systems applications

M.-C. Frank Chang, Ph.D. (National Chiao-Tung, Taiwan, 1978)
High-speed semiconductor (GaAs, InP, Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications

Panagiotis D. Christofides, Ph.D. (Minnesota, 1996)
Process modeling, dynamics and control, computational and applied mathematics

Jason (Jingsheng) Cong, Ph.D. (Illinois, 1990)
Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies

Babak Daneshrad, Ph.D. (UCLA, 1993)
Digital VLSI circuits: wireless communication systems, high-performance communications integrated circuits for wireless applications

Satish Dialgavi, Ph.D. (Stanford, 1999)
Wireless communication, information theory, wireless networks, data compression, signal processing

Deborah L. Estrin, Ph.D. (MIT, 1985)
Sensor networks, embedded network sensing, environmental monitoring, computer networks

Warren S. Grundfest, M.D., FACS (Columbia, 1980)
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms

Lei He, Ph.D. (UCLA, 1999)
Computer-aided design of VLSI circuits and systems, coarse-grain programmable systems and field programmable gate array (FPGA), high-performance interconnect modeling and design, power-efficient computer architectures

Also Professor of Mathematics

Diana L. Huffaker, Ph.D. (Texas, Austin, 1996)
Solid-state nanotechnology, MMR optoelectronic devices, solar cells, Si photonics, novel materials

Tatsuo Itoh, Ph.D. (Illinois, Urbana, 1969)
Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas; photonic bandgap structures and meta materials applications; active integrated antennas, smart antennas; RF technologies for reconfigurable front-ends; sensors and transponders

Bahram Jalali, Ph.D. (Columbia, 1989)
RF photonics, integrated optics, fiber optic integrated circuits

Laser fusion, laser acceleration of particles, non-linear optics, high-power lasers, plasma physics

Jack W. Judy, Ph.D. (UC Berkeley, 1996)
Microwaveelectromechanical systems (MEMS), micromachining, microsensors, microactuators, and microsystems, neuroengineering, neural electronic interfaces, neuroMEMS, implantable electronic systems, wireless telemetry, neural prostheses, and magnetic and neurostimulation

William J. Kaiser, Ph.D. (Wayne State, 1983)
Research and development of new microsensor and microinstrument technology for industry, science, and biomedical applications; development and applications of new atomic-resolution scanning probe microscopy methods for microelectronic device research

Alan Laub, Ph.D. (Minnesota, 1974)
Numerical linear algebra, numerical analysis, condition estimation, computer-aided control system design, high-performance computing

Xiao-Nan Liou, Ph.D. (New York U., 1971)
Radiative transfer, remote sensing of clouds and aerosols and climate/clouds-aerosols research

Jia-Ming Liu, Ph.D. (Harvard, 1982)
Nonlinear optics, ultrafast optics, laser chaos, semiconductor lasers, optoelectronics, photonics, nonlinear and ultrashort processes

Wafik B. M. Mort, Ph.D. (UCLA, 1987)
Laser and charged particle beam-plasma interactions, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics

Scientific computing, applied mathematics

C. Kumar N. Patel, Ph.D. (Stanford, 1961)
Quantum electronics; nonlinear optics; photoacoustics in gases, liquids, and solids; ultra-low level detection of trace gases; chemical and toxic gas sensors

Gregory J. Pottie, Ph.D. (McMaster U., Canada, 1988)
Communication systems and theory with applications to wireless sensor networks

Yahya Rahmat Sami, Ph.D. (Illinois, 1975)
Satellite communications antennas, personal communication antennas including human interactions, antennas for remote sensing and radio astronomy applications, advanced numerical and genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetics

Behzad Razavi, Ph.D. (Stanford, 1992)
Analog, RF, and mixed-signal integrated circuit design, dual-standard RF transceivers, phase-locked systems and frequency synthesizers, A/
including turbo codes and trellis codes, joint algorithms for distributed communication and detection
Alan N. Willson, Jr., Ph.D. (Syracuse, 1967)
Theory and application of digital signal processing including VLSI implementations, digital filter design, and signal detection
Jason C.S. Woo, Ph.D. (Stanford, 1987)
Solid-state technology, CMOS and bipolar device/circuit optimization, novel device design, modeling of integrated circuits, VLSI fabrication C.-K. Yang, Ph.D. (Stanford, 1996)
High-performance VLSI design, digital and mixed-signal circuit design
Kung Yao, Ph.D. (Princeton, 1969)
Communication theory, signal and array processing, sensor system, wireless communication systems, VLSI and systolic algorithms

**Professors Emeriti**
Frederick G. Allen, Ph.D. (Harvard, 1956)
Semiconductor physics, solid-state devices, surface physics
Francis F. Chen, Ph.D. (Harvard, 1954)
Radio frequency plasma sources and diagnostics for semiconductor processing
Harold R. Fetterman, Ph.D. (Cornell, 1968)
Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state millimeter wave structures and systems, biomedical applications of lasers
Operations research, mathematical programming, nonconvex programming, applications of mathematical programming to engineering and engineering-economic systems
Rajeev Jain, Ph.D. (Katholieke U., Leuven, Belgium, 1985)
Design of digital communications and digital signal processing circuits and systems
Nhan N. Levan, Ph.D. (Monash U., Australia, 1966)
Control systems, stability and stabilizability, errors in dynamic systems, signal analysis, wavelets, theory and applications
Dee-Son Pan, Ph.D. (Caltech, 1977)
New semiconductor devices for millimeter and RF power generation and amplification, transport in small geometry semiconductor devices, generic device modeling
Frederick W. Schott, Ph.D. (Stanford, 1949)
Electromagnetics of electronic devices, waveguide and hybrid systems; geometric nonlinear control; algebraic categorical methods
Chand R. Viswanathan, Ph.D. (UCLA, 1964)
Semiconductor electronics: VLSI devices and technology, thin oxides; reliability and failure physics of MOS devices; process-induced damage, low-frequency noise
Paul K.C. Wang, Ph.D. (UC San Diego, 2007)
CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing
Benjamin Williams, Ph.D. (MIT, 2005)
Development of terahertz quantum cascade lasers

**Adjunct Professors**
Ezio Bigleri, Dr. Ing. (Politecnico di Torino, Italy, 1967)
Digital communication, wireless channels, modulation, error-correcting codes, signal processing in telecommunications
Mary Eshagian-Winer, Ph.D. (USC, 1998)
Nanoscience and technology, heterogeneously integrated devices, nanotechnology, hardware and software co-design
Kung Yao, Ph.D. (Princeton, 1965)
Digital communication, wireless channels, modulation, error-correcting codes, signal processing in telecommunications
Joel Schulman, Ph.D. (Caltech, 1979)
Semiconductor super lattices, solid-state physics
Ingrid M. Verbauwhede, Ph.D. (Katholieke U., Leuven, Belgium, 1991)
Embedded systems, VLSI architecture and circuit design and design methodologies for applications in security, wireless communications and signal processing
El Yablonovitch, Ph.D. (Harvard, 1972)
Optoelectronics, high-speed optical communications, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication

**Adjunct Assistant Professor**
Jin Hyung Lee, Ph.D. (Stanford, 2004)
Advanced imaging techniques for biomedical applications; neurosciences and neural-engineering
Lower Division Courses
1. Electrical Engineering Physics I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 32A, 32B, Physics 1A, 1B. Introduction to modern physics and electronics with engineering orientation. Emphasis on mathematical tools necessary to express and solve Maxwell equations. Relation of these concepts to waves propagating in free space, including dielectrics and optical systems. Letter grading. Mr. Joshi, Mr. Y.E. Wang (FW).

2. Physics for Electrical Engineers. (4) Lecture, two hours; discussion, one hour; outside study, seven hours. Requisite: course 1. Introduction to concepts of modern physics necessary to understand solid-state devices, including elementary quantum theory, Fermi energies, and concepts of electronics in solids. Discussion of electric properties of semiconductors leading to operation of function devices. Letter grading. Mr. Jalali, Mr. Williams (W,Sp).

3. Introduction to Electrical Engineering. (3) Lecture, two hours; laboratory, two hours; outside study, five hours. Introduction to field of electrical engineering: research and applications across several areas, such as communications, control, electromagnetics, embedded computing, engineering optimization, integrated circuits, MEMS, nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. Letter grading. Mr. Pottie, Mr. Stafsudd (W,Sp).


19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses
100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 1 or Physics 1C, Mathematics 33A, 33B. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state circuit behavior, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.

101. Engineering Electromagnetics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mathematics 32A, 32B, or 32C and 33B. Electromagnetic field concepts, waves and phasors, transmission lines and Smith chart, transient responses, vector analysis, introduction to Maxwell equations, static and quasi-static fields. Letter grading. Mr. Ozcan, Mr. Williams (FW).


110. Circuit Analysis II. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 10. Corequisite: course 102. Sinusoidal excitation and phasors, AC steady state analysis, AC steady state power, network functions, poles and zeros, frequency domain analysis, ideal transformer, application of Laplace transforms to circuit analysis. Letter grading. Mr. Abidi, Mr. Willson (F,Sp).

110L. Circuit Measurements Laboratory. (2) Laboratory, four hours; outside study, two hours. Requisite: course 100 or 110. Experiments with basic circuits containing resistors, capacitors, inductors, and op-amps. Ohm’s law voltage and current division, Thévenin and Norton theorems, sinusoidal steady state. Letter grading. Mr. Gupta, Mr. Razavi (FW).


113D. Digital Signal Processing Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 113. Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments involving A/D and D/A converters, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for communications, speech, audio, and video using DSP chip. Letter grading. Mr. Briggs (F,Sp).

114. Speech and Image Processing Systems Design. (4) Lecture, three hours; discussion, one hour; outside study, two hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 113. Design principles of speech and image processing systems. Speech production, analysis, and modeling in first half of course; design techniques for image enhancement, filtering, and transformation in second half. Lectures supplemented by laboratory implementation of speech and image processing tasks. Letter grading. Mr. Villasenor (W).
121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 2. Introduction to principles of operation of bipolar and MOS transistors, equivalent circuits, high-frequency behavior, voltage limitations. Letter grading. Mr. Chu (W), Mr. W. O. (W, SP)

121L. Semiconductor Device Design Laboratory. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 2, 121B (may be taken concurrently). Series of experiments conducted to enable hands-on experience with better understanding of semiconductor transport parameters and semiconductor device characteristics to see interplay between various device performance metrics. Letter grading. Mr. W. O. (Not offered 2012-13)

122L. Semiconductor Devices Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisites: courses 2, 121B (may be taken concurrently). Design fabrication and characterization of p-n junction and transistors. Students perform various processing tasks such as wet preparation, oxidation, diffusion, metallization, and photolithography. Letter grading. Mr. Candler (W)

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 2. Fundamentals of solid-state properties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading. Mr. H. S. AlFalahi (F)

123B. Fundamentals of Solid-State II. (4) Lecture, three hours; outside study, nine hours. Enforced requisite: course 123A. Introduction to solid-state phenomena, band theory and semiconductor properties. Letter grading. Mr. Candler (F)

124. Semiconductor Physical Electronics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 123A. Band structure of semiconductors, experimental probes of basic band structure parameters, statistics of carriers, carrier transport properties at low fields, excess carrier transport properties, carrier recombination mechanisms, heterojunction properties. Letter grading. Mr. Candler (F)

128. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Enforced requisites: course 1, or Physics 1A and 1B. Introduction to fundamentals of nanoscience for electronics nanosystems. Principles of fundamental quantities: electron charge, effective mass, Bohr magneton, spin, as well as theoretical approaches. From these nanoscale components, discussion of basic behaviors, two lectures; laboratory analysis of dynamics, variability, and noise, contrasted with those of scaled CMOS. Incorporation of design project in which students are challenged to design electronics nanosystems. Letter grading. Mr. K. L. Wang (W)

129D. Semiconductor Processing and Device Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: laboratory 121B. Introduction to CAD tools used in integrated circuit processing and device design. Device structure optimization tool is based on PINCSES; process integration tool is based on SUIFREM. Course familiarizes students with those tools. Using CAD tools, CMOS process integration to be designed. Letter grading. Mr. Chui (Sp)

131A. Probability. (4) Lecture, four hours; discussion, one hour; outside study, 10 hours. Enforced requisite: course 102, Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables and vectors, distributions and densities, moments, characteristic functions, and limit theorems. Applications to communication, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading. Mr. Roychowdhury, Mr. Y. (F, W)

131B. Introduction to Stochastic Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. Introduction to concepts of stochastic processes, emphasizing continuous- and discrete-time stationary processes, correlation function and spectral density, linear transformation, and mean-square estimation. Applications to communication, control, and signal processing. Letter grading. Mr. Balakrishnan (Sp)


132B. Data Communications and Telecommunication Networks. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. Layered communications architectures. Queueing system modeling and analysis. Error control, flow and congestion control. Packet switching, circuit switching, and routing. Network performance, particularly layered protocols for the Internet. Computer communication concepts underlying and expected to use SEASnet computers. Letter grading. Mr. Chui (Sp)

136. Introduction to Engineering Optimization. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 1. Introduction to fundamental optimization techniques. (Same as Bioengineering CM150 and Mechanical Engineering CM160.) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and micro actuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM250L.

136A. Introductory Microwave Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101. Time-varying fields and Maxwell equations, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and antennas. Letter grading. Ms. Huftaker, Mr. Y. E. Wang (F, W, Sp)

162A. Wireless Communication Links and Antennas. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101. Basic properties of transmitting and receiving antennas and antenna arrays. Array synthesis. Adaptive arrays. Friis transmission formula, equivalent circuits. Cell-site and mobile antennas, bandwidth budget. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Rahmat-Samii (Sp)

163A. Introductory Microwave Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 161. Transmission lines, description of waveguides, impedance transformers, power dividers, directional couplers, filters, hybrid junctions, nonlinear devices. Letter grading. Mr. Y. E. Wang (F)

163B. Microwave and Millimeter Wave Active Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 121B. MESFET, HEMT, HBT, IMPATT, Gunn, small signal models, noise model, large signal model, load-pull method, parameter extraction technique. Letter grading. Mr. L. C. M. (F, W)

164D. Microwave Wireless Design. (4) Lecture, one hour; laboratory, four hours; outside study, seven hours. Enforced requisite: course 161. Microwave in-
integrated circuit design from wireless system perspective, with focus on (1) use of microwave circuit simulation tools and design flow, including use of advanced techniques, including low noise amplifier, mixer, and power amplifier, (3) knowledge and skills required in wireless integrated circuit characterization and implementation. Letter grading. Mr. Chang (Sp) 164L. Microwave Wireless Laboratory. (4) Lecture, one hour; laboratory, three hours; outside study, three hours. Enforced requisite: course 161. Measurement techniques and instrumentation for active and passive microwave components; vector signal generators, waveguides, wave meters, slotted lines, directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip and coaxial systems. Letter grading. Mr. Itto (W) 170L. Laser Laboratory. (4) (Formerly numbered 172L) Laboratory, four hours; outside study, eight hours. Enforced requisite or corequisite: course 101. Properties of lasers, including saturation, gain, mode locking, and laser oscillation, amplification, waveguides, waveguides and their applications, including communication, holography, and interferome- ter. Letter grading. Mr. Stafsudd (Sp) M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Computer Science M171L.) Laboratory, five hours; outside study, two to four hours. Recommended preparation: course M116L. Limited to seniors. Not open to students with credit for courses M161L, M162L, M164L. Communication systems laboratory covering topics in data communications. Letter grading. Mr. Abbas (Sp) 172. Introduction to Lasers and Quantum Electronics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101. Physical applications and principles of lasers, Gaussian optics, resonant cavities, atomic radiation, laser oscillation and amplification, cw and pulsed lasers. Letter grading. Mr. Abbas (Sp) 173. Photonic Devices. (4) Lecture, four hours; dis- cussion, one hour; outside study, seven hours. Enforced requisite: course 101. Introduction to basic principles of photonic devices. Topics include crystal optics, dielectrics, waveguides, semiconductor devices, electro-optic devices, magneto-optic devices, acousto-optic devices, second-harmonic generation, optical Kerr effect, optical switching devices. Letter grading. Mr. Liu (W) 173D. Photons and Communication Design. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisite: course 101. Recommended: course 132A. Introduction to mea- surement of basic photonic devices, including LEDs, lasers, detectors, and amplifiers; fiber-optic fundamentals and measurements of fiber systems. Modula- tion techniques, including A.M., F.M., phase and suppressed carrier methods. Possible projects include la- sers, optical communication, and biomedical imaging and sensing. Letter grading. Mr. Stafsudd (W) 174. Semiconductor Optoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 172. Introduction to semicon- ductor to optoelectronic devices for optical communications, interconnects, and signal pro- cessing. Basic optical properties of semiconductors, pin photodiodes, avalanche photodiode detectors (APD), light-emitting diodes (LED), semiconductor las- ers, optical modulators and amplifiers, and typical photonic systems. Letter grading. (Not offered 2012-13) 176. Photonics in Biomedical Applications. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101. Study of optical systems and their physics background. Examination of their roles in cur- rent and projected biomedical applications. Specific capabilities of photonic technologies to be related to each exam- ple (180D. Systems Design. (4) Lecture, two hours; lab- oratory, two hours; outside study, eight hours. Limited to senior Electrical Engineering majors. Advanced systems design integrating communications, control, and signal processing. A central theme in this course is new project design experience for students team to design, develop, and implement a project that runs year long to give students intensive experience on hardware design, microcontroller pro- gramming, and project coordination. Several projects based on embedded systems and software, from simple small mazes and courses offered yearly and target regional students. Projects in this course are fun and open to all students. Topics include sensing circuits and amplifier-based design, microcontroller programming, feedback control, actuation, and motor control. Letter grading. Mr. Briggs (FW) 1815. Introduction to Plasma Electronics. (4) (Same as Physics M122,) Lecture, three hours. Req- uisite: course 101 or Physics 110A. Senior-level intro- ductive course on electronics of ionized gas and applications to materials processing, generation of coherent radiation and particle beams, and renew- able energy sources. Letter grading. Mr. Mori (F) 186. Special Courses in Electrical Engineering. (4) Lecture, four hours; discussion, eight hours. Special topics in electrical engineering for undergradu- ate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. Course open to credit with topic with instructor change. Letter grading. (Not offered 2012-13) 194. Research Group Seminars: Electrical Engi- neering. (2 to 4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. May be repeated for credit. Letter grading. (FW,Sp) 199. Directed Research in Electrical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (FW,Sp) Graduate Courses 201A. VLSI Design Automation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 115C. Fundamentals of design automation of VLSI circuits and systems, including introduction to circuit and system platforms such as high-level synthesis, low-level synthesis, design verification, and testing and verification. Letter grading. Mr. He (Not offered 2012-13) 201C. Modeling of VLSI Circuits and Systems. (4) Lecture, four hours. Requisite: course 115C. Detailed study of VLSI circuit and system modeling considering analog, digital, signal integrity, performance, robustness, and manufacturability. Discussion of principles of modeling and optimization codevelopment. Letter grading. Mr. He (W) M202A. Embedded Systems. (4) (Same as Computer Science M213A) Lecture, four hours; outside study, eight hours. Designed for graduate computer science and electrical engineering students. Method- ical introduction to technologies in reconfigurable systems. Topics include hardware and software platforms for embedded systems, techniques for modeling and specification of system behavior, software or- ganization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery and energy-aware system design, timing, synchronization, fault tolerance and debugging. Letter grading. Mr. Srivastava (Sp) M202B. Energy-Aware Computing and Cyber- Physical Systems. (4) (Same as Computer Science M213B) Lecture, four hours; outside study, eight hours. Recommended: course M161 or Computer Science M51A. Recommended: course M116C or Computer Science M116L and Computer Science M151B. Systems and methods for energy-aware computing and control technologies and algorithms for improving energy sustainability in human-cyber-physical systems. Topics include modeling of energy consumption and efficiency, energy sources, and energy storage; dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware sched- uling-low-power models; battery activity and management; thermal management; sensing of power consumption. Letter grading. Mr. Srivastava (Sp) 202C. Networked Embedded Systems Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Designed for graduate computer science and electrical engineering students. Training in combination of networked embedded systems design including embedded hardware platform, em- bedded operating system, and hardware/software interface. Essential student background for research and industry career paths in wireless device development and research in areas of future wireless mobile devices to new area of wireless health. Labo- ratory design modules and course projects based on state-of-art embedded hardware platform. Letter grading. Mr. Mi (W) 205A. Matrix Analysis for Scientists and Engi- neers. (4) Lecture, four hours; outside study, eight hours. Preparation: one undergraduate linear algebra course. Designed for first-year graduate students in all branches of engineering, science, and related dis- ciplines. Introduction to matrix theory and linear alge- bra, language in which virtually all of modern science and engineering is conducted. Review of matrices and determinants, introduction to introduction to graduate-level topics. Letter grading. Mr. Laub (F) 208A. Analytical Methods of Engineering I. (4) Lecture, four hours; outside study, eight hours. Limited to graduate students. Application of linear algebra to engineering problems. Vector spaces: scalar products, Cauchy/Schwarz inequality. Gram/Schmidt orthogonalization. Matrices as linear transformations; eigenvalues and spectrum. Self- adjoint and unitary matrices. Spectral factorization, Cholesky decomposition. Determinants, Cayley/Hamilton theorem. Minimal polynomials, Bezout theorem. Positive and singular value decom- position, sequences, convergence, exponential. Applications to problems in signal process- ing, communications, and control. Letter grading. (Not offered 2012-13)

210B. Optimal Linear Estimation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131B, 210A. Mathematics 115A.Unified treatment of fundamental concepts and basic notions in adaptive filtering, Wiener filtering, Kalman filtering, and H0 filtering. Emphasis on geometric, equivalence, and duality arguments. Development of array methods and fast algorithms. Discussion of practical issues. Examples of applications from fields of signal processing, communications, biomedical engineering, finance, and control. Letter grading. Mr. Sayed (Sp)

211A. Digital Image Processing I. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Preparation: computer programming experience. Requisite: course 113. Fundamentals of digital image processing techniques and applications. Topics include two-dimensional linear system theory, image transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading. Mr. Villasenor (F)


212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems; polyphase representation; multistage implementations; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; parametric filter banks; biorthogonal transform; and its relation to multirate filter banks. Letter grading. Mr. Villasenor (Sp)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Digital filter design and optimization tools, architectures for digital signal processing circuits; integrated circuit modules for digital signal processing; programmable signal processors; CAD tools and cell libraries for application-specific integrated circuit design; case studies of speech and image processing circuits. Letter grading. (Not offered 2012-13)
224. Integrated Circuits Fabrication Processes. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 2. Basic concepts of integrated circuits fabrication processes. Technological limitations of integrated circuits design. Topics include bulk crystal and epitaxial growth, thermal oxidation, diffusion, ion-implantation, chemical vapor deposition, dry etching, lithography, and metallization. Introduction of advanced process simulation tools. Letter grading. (Not offered 2012-13)

231A. Information Theory: Channel and Source Coding. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Prerequisite: course 131A. Fundamental limits on compression and transmission of information. Topics include entropy, and error recovery algorithms for lossless data compression, channel capacity, rate versus distortion in lossy compression, and information theory for multiple users. Letter grading. (Not offered 2012-13)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 131A. Fundamentals of error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading.

232A. Stochastic Modeling with Applications to Telecommunication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Prerequisite: course 131A. Introduction to stochastic processes as applied to study of telecommunication systems and traffic engineering. Renewal theory; discrete-time Markov chains; continuous-time Markov jump processes to traffic and queueing analysis of basic telecommunication system models. Letter grading. Mc. refrigeration.

232B. Telecommunication Switching and Queueing Systems. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 232A. Queueing model and analysis with applications to space-time digital switching systems and to integrated-service telecommunication systems. Fundamental concepts of traffic engineering and queueing theory. Queue size, waiting time, busy period, blocking, and stochastic process analysis for Markovian and non-Markovian models. Letter grading.

232C. Telecommunication Architecture and Networks. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 232B. Analysis and design of integrated-service telecommunication networks and multiple-access procedures. Stochastic analysis of priority-based queueing system models. Queueing networks; network protocol architectures; error control; routing, flow, and access control. Applications to local-area, packet-radio, satellite, and computer communication networks. Letter grading. (Not offered 2012-13)

232D. Telecommunication Networks and Multiple-Access Systems. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 232B. Performance analysis and design of telecommunication networks and multiple-access communication systems. Topics include architectures, multiplexers, and multiple-access message error control; error/flow control; switching, routing, protocols. Applications to local-area, packet-radio, local-distribution, computer and satellite communication networks. Letter grading. (Not offered 2012-13)

232E. Graphs and Network Flows. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 136. Solution to analysis and synthesis problems that may be formulated as flow problems in capacity constrained (or cost constrained) networks. Development of tools of network flow theory using graph theoretic methods; application to computer communication, transportation, and transmission problems. Applications to circuit-switching and packet-switching. Mr. Roychowdhury (Sp)

233. Wireless Communications Systems. (4) Formerly numbered 233B.) Lecture, four hours; outside study, eight hours. Prerequisite: course 230B. Various aspects of physical layer design for wireless communications systems. Topics include wireless signal propagation and channel modeling, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access schemes, transceiver design and effects of non-ideal components, hardware partitioning issues. Case study highlights system level trade-offs. Letter grading. Mr. Daneshgar (Sp)


236B. Convex Optimization. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 236A. Introduction to convex optimization and its applications. Convex sets, functions, and basics of convex analysis. Convex optimization problems and their applications. Quadratic programming and semi-definite programming. Lagrange duality and optimality conditions. Applications of convex optimization. Unconstrained minimization methods. Interior-point and cutting-plane algorithms. Introduction to nonlinear programming. Letter grading. Mr. Vanderberghe (Sp)

236C. Optimization Methods for Large-Scale Systems. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 236B. Theory and computational procedures for decomposing large-scale optimization problems: cutting-plane methods, column generation, decomposition. Various modern techniques for global continuous optimization: branch-and-bound methods, reverse convex programming, biconvex and multiconvex optimization, genetic algorithms, simulated annealing. Introduction to interior-point optimization. Letter grading. (Not offered 2012-13)

237. Multimedia Communications and Processing. (4) Lecture, four hours; outside study, eight hours. Prerequisite: courses 113, 131A. Key concepts, principles, and algorithms of multimedia communications and processing across heterogeneous Internet and wireless communication systems. Due to flexible and low-cost infrastructure, new networks and communication channels enable design of new services required by delay-sensitive, bandwidth-intensive, and loss-tolerant multimedia applications. New concepts, principles, theories, and practical solutions for cross-layer design that can provide optimal adaptation for time-varying channel characteristics, adaptive and delay-sensitive applications, and multimedia transmission environments. Letter grading. (Not offered 2012-13)

239A. Special Topics in Signals and Systems. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of signal and systems, such as communications, control, image processing, information theory, multimedia, network coding, optimization, speech processing, telecommunication, and VLSI signal processing. May be repeated for credit with topic change. S/U or letter grading. Mr. Balakrishnan, Mr. Diggavi, Ms. Dolecek, Mr. Roychowdhury (FW, Sp)

239BS. Seminar: Signals and Systems. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing.
CM250A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Bioengineering M250B and Mechanical and Aerospace Engineering CM280A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4A, 4L. BL. Introduction to micromachining technology and methods for analysis and design, in particular linear state-space models; sigma algebra equivalence and Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observer design principle. Connections with transfer function techniques. Letter grading. (Not offered 2012-13)

M240C. Optimal Control. (4) (Same as Chemical Engineering M280C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisite: course 141. M240A. Introduction to optimal control, with emphasis on detailed study of LQR, or linear regulators (not offered 2012-13). Lecture, one hour; laboratory, four hours; outside study, four hours. Requisite: course CM150 or CM250A. Advanced discussion of micro-machining processes used to construct MEMS. Covariance of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. Candler (Sp)

M250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M250B and Mechanical and Aerospace Engineering M280B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced prerequisite: course CM150 or CM250A. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. Candler (Sp)

M262. Antenna Theory and Design. (4) (Same as Bioengineering M262 and Mechanical and Aerospace Engineering M280.) Lecture, four hours; laboratory, three hours; outside study, four hours. Requisite: course CM250A. Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4A, 4L. BL. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM150L. Letter grading. Mr. Candler (Sp)

M262L. Antenna Theory and Design Laboratory. (4) (Same as Bioengineering M262L and Mechanical and Aerospace Engineering M280L.) Lecture, one hour; laboratory, four hours; outside study, eight hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and non-foundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Candler (Sp)

M265. Neuroengineering. (4) (Same as Bioengineering M265 and Mechanical and Aerospace Engineering M280.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. Introduction to principles and technologies of bio-electronics, bio-optics, and bio-sensors. Examination of concepts and numerical techniques in electromagnetics. Numerical techniques based on method of moments. Letter grading. Mr. Mr. Rahmat-Samii (W)


M286. Seminar: Topics. (2) Same as Chemical Engineering M286 and Mechanical and Aerospace Engineering M299A.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading academic researchers in various areas of microelectronics, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.


274. Fiber Optic System Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 173D and/or 174. Top-down introduction to physical layer design in fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-aided design. Architectural-level design of fiber optic transceiver circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading. Mr. Dzhazhize (F)

279AS. Special Topics in Physical and Wave Electronics. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U or letter grading. Ms. Huffaker, Jr. Moshi (F,Sp)

279BS. Seminar: Physical and Wave Electronics. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. (Not offered 2012-13)

279CS. Clean Green IGERT Brown-Bag Seminar. (1) Seminar, one hour. Required of students in Clean Energy for Green Industry (IGERT) Research. Lecture seminar presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. Ms. Huffaker (F,Sp)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and streaming instabilities. Application to experiments in fully and partially ionized gases. Letter grading. (Not offered 2012-13)

285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M185, and 285A or Physics 222A. Interaction of intense electromagnetic waves with plasmas: waves in inhomogeneous and bound-plasmas, nonlinear wave coupling and damping, parametric instabilities, anomalous resistivity, shock waves, echoes, laser heating. Emphasis on experimental considerations and techniques. Letter grading. (Not offered 2012-13)


295. Academic Technical Writing for Electrical Engineers. (3) Seminar, three hours. Designed for electrical engineering Ph.D. students who have completed preliminary examinations. Students read models of good writing and learn to make rhetorical observations and writing decisions, improve their academic and technical writing skills by writing and revising conference and journal papers, and practice writing for and speaking to various audiences, including potential students, engineers outside their specific fields, and nonengineers (colleagues outside field, policymakers, etc.). Students write in variety of genres, all related to their professional development as electrical engineers. Emphasis on writing as vital way to communicate precise technical and professional information in distinct contexts, directly resulting in specific outcomes. S/U grading. (F, W, Sp)

296. Seminar: Research Topics in Electrical Engineering. (2) Seminar, two hours; outside study, four hours. Advanced study and analysis of current topics in electrical engineering. Discussion of current research and literature in research specialty of faculty member teaching course. May be repeated for credit. S/U grading.

297. Seminar Series: Electrical Engineering. (1) Seminar, 90 minutes; outside study, 90 minutes. Limited to graduate electrical engineering students. Weekly seminars and discussion by invited speakers on research topics of heightened interest. S/U grading. (F, W, Sp)

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate electrical engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. S/U or letter grading. (Not offered 2012-13)

299. M.S. Project Seminar. (4) Seminar, to be arranged. Required of all M.S. students not in thesis option. Supervised research in small groups or individually under guidance of faculty mentor. Regular meetings, culminating report, and presentation required. Individual contract required; enrollment petition available in Office of Graduate Student Affairs. S/U grading. Mr. Tabuada (F, Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading. (F, W, Sp)


596. Directed Individual or Tutorial Studies. (2 to 8) Tutorial, to be arranged. Limited to graduate electrical engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate electrical engineering students. Reading and preparation for M.S. comprehensive examination. S/U grading.
Materials Science and Engineering

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Yong Chen, Ph.D., Kosmas Galatsis, Ph.D.
Adjunct Associate Professors
Suneel Kodambaka, Ph.D., Ioanna Kakoulli, D.Phil.
Associate Professors
Alfred S. Yue, Ph.D., George H. Sines, Ph.D.
Aly H. Shabaik, Ph.D., John D. Mackenzie, Ph.D.
William Klement, Jr., Ph.D., Alan J. Ardell, Ph.D.
Professors Emeriti
King-Ning Tu, Ph.D., Robert F. Hicks, Ph.D.
Vijay Gupta, Ph.D., Mark S. Goorsky, Ph.D.
Nasr M. Ghoniem, Ph.D., Jane P. Chang, Ph.D.
Gregory P. Carman, Ph.D., Gregory P. Carman, Ph.D.
Russel E. Caflisch, Ph.D.
Professors
Qibing Pei, Ph.D., Mark S. Goorsky, Ph.D.
Vice Chair

Scope and Objectives
At the heart of materials science is an understanding of the microstructure of solids. "Microstructure" is used broadly in reference to solids viewed at the subatomic (electronic) and atomic levels, and the nature of the defects at these levels. The microstructure of solids at various levels profoundly influences the mechanical, electronic, chemical, and biological properties of solids. The phenomenological and mechanistic relationships between microstructure and the macroscopic properties of solids are, in essence, what materials science is all about.

Materials engineering builds on the foundation of materials science and is concerned with the design, fabrication, and optimal selection of engineering materials that must simultaneously fulfill dimensional, property, quality control, and economic requirements.

The department also has a program in electronic materials that provides a broad-based background in materials science, with opportunity to specialize in the study of those materials used for electronic and optoelectronic applications. The program incorporates several courses in electrical engineering in addition to those in the materials science curriculum.

The undergraduate program leads to the B.S. degree in Materials Engineering. Students are introduced to the basic principles of metallurgy and ceramic and polymer science as part of the department’s Materials Engineering major.

A joint major field, Chemistry/Materials Science, is offered to students enrolled in the Department of Chemistry and Biochemistry (College of Letters and Science).

The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

Department Mission
The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

Undergraduate Program Objectives
The materials engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The Materials Engineering major at UCLA prepares undergraduate students for employment or advanced studies with industry, the national laboratories, state and federal agencies, and academia. To meet the needs of these constituencies, the objectives of the undergraduate program are to produce graduates who (1) possess a solid foundation in materials science and engineering, with emphasis on the fundamental scientific and engineering principles that govern the microstructure, properties, processing, and performance of all classes of engineering materials, (2) understand materials processes and the application of general natural science and engineering principles to the analysis and design of materials, (3) have strong skills in independent learning, analysis, and problem solving, with special emphasis on design of engineering materials and processes, communication, and an ability to work in teams, and (4) understand and are aware of the broad issues relevant to materials, including professional and ethical responsibilities, impact of materials engineering on society and environment, contemporary issues, and need for lifelong learning.

Undergraduate Study
The Materials Engineering major is a designated capstone major. Students undertake two individual projects involving materials selection, treatment, and serviceability. Successful completion requires working knowledge of physical properties of materials, and strategies and methodologies of using materials properties in the materials selection process. Students learn and work independently and practice leadership and teamwork in and across disciplines. They are also expected to communicate effectively in oral, graphic, and written forms.

Materials Engineering B.S.
Capstone Major
The materials engineering program is designed for students who wish to pursue a professional career in the materials field and desire a broad understanding of the relationship between microstructure and properties of materials. Metals, ceramics, and polymers, as well as the design, fabrication, and
testing of metallic and other materials such as oxides, glasses, and fiber-reinforced composites, are included in the course contents.

**Materials Engineering Option**

**Preparation for the Major**  
*Required:* Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1).

**The Major**  
*Required:* Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Civil and Environmental Engineering 101 (or Mechanical and Aerospace Engineering 101), 108, Electrical Engineering 100, Materials Science and Engineering 104, 110, 110L, 120, 130, 131, 131L, 132, 143A, 150, 160, Mechanical and Aerospace Engineering 181A or 182A; two laboratory courses (4 units) from Materials Science and Engineering 121L, 141L, 143L, 161L; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and three major field elective courses (12 units) from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical Engineering 2, 123A, 123B, 124, Materials Science and Engineering C111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C, plus at least one elective course (4 units) from Chemistry and Biochemistry 30A, 30AL, Electrical Engineering 131A, Materials Science and Engineering 170, 171, Mathematics 170A, or Statistics 100A.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

**Electronic Materials Option**

**Preparation for the Major**  
*Required:* Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Electrical Engineering 10; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1).

**The Major**  
*Required:* Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Electrical Engineering 101, 121B, Materials Science and Engineering 104, 110, 110L, 120 (or Electrical Engineering 2), 121, 121L, 122, 130, 131, 131L, Mechanical and Aerospace Engineering 101, and 181A or 182A; four courses (16 units) from Electrical Engineering 123A, 123B, Materials Science and Engineering 132, 150, 160; 4 laboratory units from Electrical Engineering 172L, Materials Science and Engineering 141L, 161L, 199; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and one major field elective course (4 units) from Electrical Engineering 110, 124, 131A, 172, Materials Science and Engineering C111, 143A, 162.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

**Graduate Study**

For information on graduate admission, see Graduate Programs, page 23.

The following introductory information is based on the 2012-13 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrq intro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

The Department of Materials Science and Engineering offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Materials Science and Engineering.

**Materials Science and Engineering M.S.**

**Areas of Study**

There are three main areas in the M.S. program: ceramics and ceramic processing, electronic and optical materials, and structural materials. Students may specialize in any one of the three areas, although most students are more interested in a broader education and select a variety of courses. Basically, students select courses that serve their interests best in regard to thesis research and job prospects.

**Course Requirements**

*Thesis Plan.* Nine courses are required, of which six must be graduate courses. The courses are to be selected from the following lists, although suitable substitutions can be made from other engineering disciplines or from chemistry and physics with the approval of the departmental graduate adviser. Two of the six graduate courses may be Materials Science and Engineering 598 (thesis research).

*Comprehensive Examination Plan.* Nine courses are required, six of which must be graduate courses, selected from the following lists with the same provisions listed under the thesis plan. The remaining three courses in the total course requirement may be upper division courses.

Ceramics and ceramic processing: Materials Science and Engineering C111, 121, 122, 143A, 151, 161, 162, 200, 201, C211, 246D, 258B.

Electronic and optical materials: Materials Science and Engineering C111, 121, 122,
143A, 151, 161, 162, 200, 201, 221, 222, 223, 286.


As long as a majority of the courses taken are offered by the department, substitutions may be made with the consent of the departmental graduate adviser.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Thesis Plan
In addition to fulfilling the course requirements, the student is required to write a thesis on a research topic in materials science and engineering supervised by the thesis adviser. An M.S. thesis committee composed of three departmental faculty members, including the thesis chair, reviews and approves the thesis.

Comprehensive Examination Plan
Consult the graduate adviser for details. If the comprehensive examination is failed, students may be reexamined once with the consent of the graduate adviser.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines
Ceramics and ceramic processing, electronic and optical materials, and structural materials.

Course Requirements
There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed to satisfy the written preliminary examination requirement. In this case, a grade-point average of at least 3.33 in all courses is required, with a grade of B- or better in each course.

The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of knowledge contained in nine courses, at least six of which must be graduate courses, plus the current literature in the area of specialization. Materials Science and Engineering 599 may not be applied toward the nine-course total. The major fields named above are described in a Ph.D. major field syllabus, each of which can be obtained in the department office.

The minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor field is selected to support the major field and is usually a subset of the major field.

For information on completing the Engineer degree, see Schoolwide Programs, Courses, and Faculty.

Written and Oral Qualifying Examinations
During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination that encompasses the body of knowledge in materials science equivalent to that expected of a bachelor’s degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice. After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. Faculty members holding joint appointments with the department are considered inside members.

Fields of Study

Ceramics and Ceramic Processing
The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials
The electronic and optical materials field provides an area of study in the science and technology of electronic materials that includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials
The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities
Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Electron Microscopy Laboratories with a scanning transmission electron microscope (100 keV), a field emission trans-
mission electron microscope (200 keV), and a scanning electron microscope, all equipped with a full quantitative analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes

- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Nano-Materials Laboratory
- Nondestructive Testing Laboratory
- Organic Electronic Materials Processing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonders
- X-Ray Diffraction Laboratory
- X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors

Theory and numerical simulation for materials physics, epitaxial growth, nanoscale systems, semiconductor device properties and design in applications to quantum well devices, quantum dots, nanocrystals and quantum computing

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models, fatigue characterization of piezoelectric ceramics, magnetostatic composites, characterizing shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally evaluating damage in composites

Jane P. Chang, Ph.D. (MIT, 1998)
Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry

Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, nanoscale and microscale electronic, mechatronic, optical, biological, and sensing devices, circuits and systems

Bruce S. Dunn, Ph.D. (UCLA, 1974)
Solid electrolytes, electrical properties of ceramics and glasses, ceramic-metal bonding, optical materials

Nasir M. Ghoniem, Ph.D. (Wisconsin, 1977)
Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relaxation in optical semiconductors and device structures, high-resolution X-ray diffraction of semiconductors, ceramics, and high-strength alloys

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms, synthesis and characterization of composite materials, ice mechanics

Robert F. Hicks, Ph.D. (UC Berkeley, 1984)
Chemical vapor deposition and atmospheric plasma processing of materials

Richard B. Kaner, Ph.D. (Pennsylvania, 1984)
Rapid synthesis of high-temperature materials, conducting polymers as separation membranes for enantiomers, synthesis of carbon nanotubes and composites

Vidvuds Ozolins, Ph.D. (Kungliga Tekniska Högskolan, Sweden, 1998)
Theory of materials, first-principles modeling of phase transformations in bulk and surface systems, vibrational and electronic properties

Qibing Pei, Ph.D. (Chinese Academy of Sciences, 1990)
Electroactive polymers through molecular design and nano-engineering for electronic devices and artificial muscles

Dwight C. Streit, Ph.D. (UCLA, 1986)
Properties of electronic materials, characterization techniques, correlation of material and device performance

Sarah H. Tolbert, Ph.D. (UC Berkeley, 1995)
Self-organized nanostructured materials for energy storage, energy harvesting, nanomagnetics and nanoelectronics

King-Ning Tu, Ph.D. (Harvard, 1968)
Kinetic processes in thin films, metal-silicon interfaces, electromigration, Pb-free interconnects

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoelectronics and optoelectronics, nano and molecular devices, MBE and superlattices, microwave and millimeter electronics, quantum information

Paul S. Weiss, Ph.D. (UC Berkeley, 1986)
Atomic-scale surface chemistry and physics, molecular devices, nanolithography, biophysics and neuroscience, nanometer-scale electronics and storage, surface interactions, surface motion, dynamics, and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes

Processing, characterization, and controlled delivery of biological molecules of bioerodible polymers; design and fabrication of tissue engineering scaffolds; tissue-material interactions and dental biomaterials

Ya-Hong Ye, Ph.D. (UCLA, 1986)
Heteroepitaxial growth of semiconductor thin films: strained Si, self-assembled quantum dots, and other epitaxial nano-structures; Si substrate impedance engineering for mixed-signal integrated circuit technologies

Jenn-Ming Yang, Ph.D. (Delaware, 1986)
Mechanical behavior of polymer, metal, and ceramic matrix composites, electronics packaging

Yang Yang, Ph.D. (Massachusetts-Lowell, 1992)
Conjugated polymers and applications in optoelectronic devices such as light-emitting diodes, photodiodes, and field-effect transistors

Professors Emeriti

Alan J. Ardell, Ph.D. (Stanford, 1964)
Irradiation-induced precipitation, high-temperature deformation of solids, electron microscopy, physical metallurgy of aluminum/titinum alloys, precipitation hardening

David L. Douglass, Ph.D. (Ohio State, 1958)
Oxidation and sulfidation kinetics and mechanisms, materials compatibility, defect structures, diffusion

William Klement, Jr., Ph.D. (Caltech, 1962)
Phase transformations in solids, high-pressure effects on solids

Glass science, ceramics, electrical properties of amorphous materials, materials recycling

Kanj I Ono, Ph.D. (Northwestern, 1964)
Mechanical behavior and nondestructive testing of structural materials, acoustic emission, dislocations and strengthening mechanisms, microstructural effects, and ultrasonics

Aly H. Shabaik, Ph.D. (UC Berkeley, 1966)
Metal forming, metal cutting, mechanical properties, friction and wear, biomaterials, manufacturing processes

George H. Sines, Ph.D. (UCLA, 1953)
Fracture of ceramics, fatigue of metals, carbon-carbon composites, failure analysis

Christian N.J. Wagner, Dr. rer. nat. (U. des Saarlandes, 1957)
X-ray and neutron diffraction; structure of liquid and amorphous alloys, and plastically deformed metals; biomaterials; thin films; residual stresses

Alfred S. Yue, Ph.D. (Purdue, 1957)
Semiconductor eutectics; electronic materials for solar cell and detector applications, solidification and crystal growth

Associate Professors

Yu Huang, Ph.D. (Harvard, 2003)
Nano-material fabrication and development, bio-nano structures

Ioanna Kakoulidou, D.Phil. (U. Oxford, United Kingdom, 1999)
Chemical and physical properties of non-metallic archaeological materials; alteration processes in archaeological vitreous materials and pigments

Assistant Professor

Suneel Kodambaka, Ph.D. (Illinois, Urbana-Champaign, 2002)
In situ microscopy, surface thermodynamics, kinetics of crystal growth, phase transformations and chemical reactions, thin film physics

Adjunct Professor

Harry Patton Gillis, Ph.D. (Chicago, 1974)
Application of surface science and chemical dynamics techniques to elucidate fundamental molecular mechanisms and optimize practical processes

Adjunct Associate Professors

Eric P. Bescher, Ph.D. (UCLA, 1987)
Advanced cementitious materials, sol-gel materials, organic/inorganic composites

Kosmas Galatisis, Ph.D. (RMIT U., Australia, 2002)
Dilute magnetic semiconductors for Spintronics applications, nano-technology; understanding of alternative state variables for electronic devices

Lower Division Courses

10. Freshman Seminar: New Materials. (1) Seminar, one hour; outside study, two hours. Preparation: high school chemistry and physics. Not open to students with credit for course 104. Introduction to basic concepts of materials science and new materials vital to advanced technology. Microstructural analysis and various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. Letter grading. Sr. Kodambaka (F)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.
Upper Division Courses

104. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, 20L, Physics 1A, 1B. General introduction to different types of materials used in engineering designs: metals, ceramics, plastics, and composites, relationship between structure (crystals and microstructure) and properties of technological materials, illustration of their fundamental differences and their applications in engineering. Letter grading. Mr. Dunn (F,W,Sp) 99. Student Research Program. (1 to 2) Lecture, four hours; discussion, one hour; outside study, eight hours per week. Unit-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

110. Introduction to Materials Characterization A (Crystal Structure, Nanostructures, and X-Ray Scattering). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 104. Modern methods of materials characterization: fundamentals of crystallography, properties of X-ray scattering; powder method; Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; use of x-ray spectrometry; design of materials characterization procedures. Letter grading. Mr. Goorsky (F) 110L. Introduction to Materials Characterization A Laboratory. (2) Laboratory, four hours; outside study, two hours. Requisite: course 104. Experimental techniques and analysis of materials through X-ray scattering techniques; powder method, crystal structure determination, high-resolution X-ray diffraction methods, use of x-ray spectrometry. Letter grading. Mr. Goorsky (F) 111. Introduction to Materials Characterization B (Electron Microscopy). (4) (Formerly numbered 111.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereo- graphic projection, direct observation of defects in crystals, replicas; scanning electron microscopy: emissive and reflective modes; chemical analysis; electron optics of both instruments. Concurrently scheduled with course C211. Letter grading. Mr. Kodambaka (W) 112. Cultural Materials Science II: In Vitro Microscopy and Microanalysis. (4) Lecture, three hours; laboratory, two hours. Preparation: general chemistry, or inorganic and organic chemistry. Methodology of sampling and microanalysis of cultural materials for study of their morphology, microscopy, and composition by applying in vitro optical, chemical, and instrumental methods. Topics include optical microscopy, electron microscopy, x-ray diffraction, infrared spectroscopy, X-ray diffraction, infrared spectroscopy, chemical spot tests, and chromatography. Hands-on experience through object-based problem-solving approach. Practical skills acquired on sampling and sample preparation methods of cultural materials and on analysis of microsamples using basic instruments for characterization of organic and inorganic compounds currently scheduled with course CM212. Letter grading. 120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 110 (or Chemistry 113A). Introduction to physical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading. Mr. Y. Yang (W) 121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Corequisite: course 120. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization. Experimental, optical, and ion-beam techniques. Heterostructures, band-gap engineering, development of new materials for optoelectronic applications. Letter grading. Ms. Huang (Sp) 121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Corequisite: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading. Mr. Goorsky (Sp) 122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading. Mr. Goorsky (W) 130. Phase Relations in Solids. (4) Lecture, four hours; discussion, seven hours; outside study, four hours. Requisites: course 104, and Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A. Summary of thermodynamic laws, equilibrium criteria, and mass-action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Xie (F) 131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermediate phases, gas-solid reactions, design of oxidation-resistant alloys, recrystallization, and grain growth. Letter grading. Mr. Tu (W) 131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Corequisite: course 131. Design of heat-treating cycles and performing experiments to study interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. Mr. Tu (W) 132. Structure and Properties of Metallic Alloys. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, 131. Physical metals, lightweight alloys (Al and Ti), and superalloys. Strengthening mechanisms, microstructural control methods for strength and toughness improvement. Grain boundary segregation. Letter grading. Mr. J-M. Yang (Sp) 133. Ancient and Historic Metals: Technology, Microstructure, and Corrosion. (4) Lecture, two hours; discussion, four hours; outside study, eight hours. Preparation: courses 130, 135. Analysis of ancient and historic metal artifacts. Identification of metals and their alloys, surface patination, metallic coatings, corrosion, and microstructure of ancient and historic metals. Extensive laboratory work in preparation and examination of metallic samples under microscope, as well as lectures on technology of metal artifacts. Practical instruction in metallographic microscopy. Exploration of phase and stability diagrams of common systems, numerical and analytical techniques appropriate for examination and characterization of metallic artifacts. Concurrency scheduled with course CM233. Letter grading. 140. Materials Selection and Engineering Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymers, ceramics, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Project assignments. Letter grading. Mr. Dunn (F,Sp) 141L. Computer Methods and Instrumentation in Materials Science. (2) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to juniors/senior Materials Science and Engineering majors. Interpreting and developing software for real-time data acquisition and processing, computer-aided testing. Letter grading. Mr. Goorsky (W) 143A. Mechanical Behavior of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: course 130. Introduction to Mechanical and Aerospace Engineering 101. Plastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocations, fracture, microstructural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. J-M. Yang (W) 143L. Mechanical Behavior Laboratory. (2) Laboratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Methods of characterizing mechanical behavior of various materials; elastic and plastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. Dunn (W) 150. Introduction to Polymers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, stress-strain relationship, and their effects on physical properties. Glassy polymers, springy polymers, elastomers, adhesives. Fiber forming polymers, polymer processing technology, plastics and adhesives. Letter grading. Mr. Ou (Sp) 151. Structure and Properties of Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: at least two courses from 132, 143A, 150, 160. Requisite: course 104. Relationship between structure and mechanical properties of composite materials with fiber and particulate reinforcement. Properties of fiber, matrix, and interfaces. Selection of macrostructures and manufacturing. Letter grading. Mr. J-M. Yang (Sp) 160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 130. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading. Mr. Dunn (F) 161. Processing of Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour. Requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Preparation: course 135. Introduction to modern techniques of powder synthesis, greenware forming, sintering, glass melting. Microstructure properties relations in ceramics. Fracture analysis and design of ceramics. Letter grading. Mr. Dunn (F)
Graduate Courses

200. Principles of Materials Science I (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Lattice dynamics and thermal properties of solids, classical and quantized free electron theory, electrons in a periodic potential, transport in semi-conductors, magnetic and magnetic properties of solids. Letter grading. Mr. Dunn (Sp)


C211. Introduction to Materials Characterization B (Electron Microscopy). (4) (Formerly numbered 211.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization before and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replication of specimens, transmission electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Concurrently scheduled with course C111. Letter grading. Mr. Xie

CM212. Cultural Materials Science II: In Vitro Microscopy and Microanalysis. (4) (Same as Conservation M210.) Lecture, three hours; laboratory, two hours. Preparation of general or organic and inorganic chemistry. Methodology of sampling and microanalysis of cultural materials for study of their morphology, microstructure, and composition by applying in vitro optical, chemical, and instrumental methods. Topics include optical and electron microscopy, X-ray and electron spectroscopy, X-ray diffraction, infrared spectroscopy, chemical spot tests, and chromatography. Hands-on experience through object-based problem-solving approach. Practical skills acquired on sampling and sample preparation methods of cultural materials and on analysis of microsamples. Emphasis on techniques used for determining composition and structure of cultural materials and the use of reference materials. Concurrently scheduled with course C111. Letter grading. Mr. W. (W)

M215. Techniques and Materials of Archaeological and Cultural Materials: In Situ and Ex Situ Architectural Surfaces. (4) (Same as Art History M203F and Conservation M250.) Seminar, two hours; laboratory, three hours. Requisite: course M216 or C112 or Conservation M210. Recommended: Conservation M215. Designed for graduate conservation and art history students. Principles of archaeological conservation of in situ and ex situ monumental archaeological and cultural materials, with focus on rock art, wall paintings, ceramics, sculp- ture, decorative architectural elements, and mosaics, through study of their constituent material and tech- niques in context of their geographical and chronolo- gical occurrence, technological developments, physical and conservation history, and physical loca- tion. Lectures, seminars, and case-study presenta- tions, museum and site visits, hands-on laboratory experiences, and individual research that incorpo- rates literary survey of archaeological and conserva- tion records, scientific data, and ancient treatises. Letter grading.

M216. Science of Conservation Materials and Methods I (4) (Same as Conservation M216.) Seminar, one hour; laboratory, three hours. Recommend- ed requisite: course 104. Introduction to physical, chemical, and mechanical properties of conservation materials (employed for preservation of archaeological and cultural materials) and their aging character- istics. Science and application methods of traditional conservation and inorganic analysis: application of novel technology based on biomimeralization pro- cesses and nanostructured materials. Letter grading.

221. Science of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Study of major physical and chemical principles affecting properties and performance of semiconductor materials. Topics include bonding, carrier statistics, band-gap engineering, optical and transport properties, novel materials systems, and characterization. Letter grading. Mr. Goorsky (Sp)


223. Materials Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131, 139, 140. Fabrication, structure, and proper- ty correlations of thin films made of microelectronics for data and information storage. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading. Mr. Goorsky (W)

224. Deposition Technologies and Their Applica- tions. (4) Lecture, four hours; outside study, eight hours. Examination of physics behind majority of modern thin film deposition technologies based on various physical and chemical vapor deposition processes. Letter grading. Mr. Xie


226. Si-CMOS Technologies: Selected Topics in Materials Science. (4) Lecture, three hours; discus- sion, one hour; outside study, eight hours. Recommended preparation: Electrical Engineering 221B. Requisites: courses 130, 131, 200, 221, 222. Select- ed topics in materials science from modern Si-CMOS technology, including technological challenges in high k/metal gate stacks, strained Si FETs, SOI and three-dimensional FETs, source/drain engineering including transient-enhanced diffusion, nonvolatile memory, and metallization for ohmic contacts. Letter grading. Mr. Xie

CM233. Ancient and Historic Metals: Technology, Microstructure, and Corrosion. (4) (Same as Conser- vation M246L.) Lecture, two hours; laboratory, 90 minutes. Designed for graduate conservation and materials science students. Processes of extraction, alloying, surface patina formation, corrosion, and microstructure of ancient and historic met- als. Extensive laboratory work in preparation and ex- amination of metallic samples under microscope, as well as lectures on technology of metallic works of art. Practical instruction in metallographic micros- copy. Exploration of phase and stability diagrams of common alloying systems and environments and an- alytical techniques appropriate for examination and characterization of metallic artifacts. Concurrently scheduled with course C133. Letter grading.
Materials Science and Engineering / 95

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to basic concepts of fracture mechanics, fatigue, fracture in reactive environments, and alloy development. Letter grading. Mr. Dunn (W, even years)

243C. Dislocations and Strengthening Mechanisms in Solids. (4) Lecture, four hours; outside study, eight hours. Preparation: course 143A. Elastic and plastic behavior of crystallites, dislocations, mechanical interaction, and theory of dislocations. Lecture grading. Mr. Xie (F; odd years)

246B. Structure and Properties of Glass. (4) Lecture, one hour; outside study, eight hours. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; outside study, eight hours. Preparation: course 160. Principles of electronic and optical properties of ceramic single crystals and glasses and effects of processing and microstructure on these properties. Electronic conduction, ferroelectricity, and optical properties. Mechanism, electrical, and optical properties of glass and relationship to structure. Letter grading. Mr. Dunn (W, even years)

248. Materials and Physics of Solar Cells. (4) Lecture, four hours. Preparation: introductory course 149A. Introduction to materials and physics of photovoltaic cell, covering basic physics of semiconductors in photovoltaic devices, physical models of cell operation, characteristics and design of common types of solar cells, and approaches to increasing solar cell efficiency. Recent progress in solar cells, such as organic solar cell, thin-film solar cells, and multiple junction solar cells provided to increase student knowledge. Tour of research laboratory included. Letter grading. Mr. Y. Wang (Sp, even years)


251. Chemistry of Soft Materials. (4) Lecture, four hours. Preparation: introductory course 149A. Introduction to soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic molecules, synthetic polymers, and biomolecules and biomaterials. Extensive description and discussion of structure-property relationship, spectroscopic and experimental techniques, and preparation methods for various soft materials. Letter grading. Mr. Pei (F)

252. Organic Polymer Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers: heavily doped, highly conducting polymers; applications as processable metals and in various electrical, optical, and electrochemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

260. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Preparation: course 149A. Current topics in materials science and engineering. Letter grading. Mr. Wu (W)

261. Seminar: Advanced Topics in Materials Science and Engineering. (2) Seminar, two hours; outside study, four hours. Preparation: course 149A. Current topics in materials science and engineering. Research seminar in which current research is presented. May be arranged. May be repeated up to three times for credit. Letter grading. Mr. J. Y. Yang

265. Directed Individual or Tutorial Studies. (2 to 8) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

271. Electronic Structure of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: basic knowledge of quantum mechanics. Recommended prerequisite: course 200. Introduction to modern first-principles electronic structure calculations for various types of modern materials. Properties of electrons and interatomic bonding in molecules, crystals, and liquids, with emphasis on practical methods for solving Schrodinger equation and using to calculate physical properties such as elastic constants, equilibrium structures, binding energies, vibrational frequencies, electronic band gaps and band structures, properties of defects, surfaces, interfaces, and magnetism. Extensive hands-on experience with modern density-functional theory code. Letter grading. Mr. Ozolins (W)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Strongly recommended prerequisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding of basic principles that distinguish nanostructures (with feature size below 100 nanometers) from more common microstructured materials. Explanation of new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics include structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assembly on surfaces and in liquid solutions, mechanical properties of nanostructured metamaterials, molecular electronics, spin-based electronics, and proposed realizations of quantum computing. Discussion of current and future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. Ozolins (F)

CM280. Introduction to Biomaterials. (4) (Same as Bioengineering CM278.) Lecture, three hours; discussion, two hours; outside study, seven hours. Preparation: courses 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between materials properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (W)

298. Seminar: Advanced Topics in Materials Science and Engineering. (2) Seminar, two hours; outside study, four hours. Preparation: course 149A. Advanced study and analysis of current topics in materials science and engineering. Research seminar in which current research and literature in research specialty of faculty members teaching course. May be repeated for credit. S/U grading. Mr. J. A. Y. Yang

299. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate materials science and engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for course and instruction. May be repeated for credit. S/U grading. (F,W,Sp)
Mechanical and Aerospace Engineering

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Scope and Objectives

The Department of Mechanical and Aerospace Engineering offers curricula in aerospace engineering and mechanical engineering at both the undergraduate and graduate levels. The scope of the departmental research and teaching program is broad, encompassing dynamics, fluid mechanics, heat and mass transfer, manufacturing and design, nanoelectromechanical and microelectromechanical systems, structural and solid mechanics, and systems and control. The applications of mechanical and aerospace engineering are quite diverse, including aircraft, spacecraft, automobiles, energy and propulsion systems, robotics, machinery, manufacturing and materials processing, microelectronics, biological systems, and more.

At the undergraduate level, the department offers accredited programs leading to B.S. degrees in Aerospace Engineering and in Mechanical Engineering. The graduate level, the department offers programs leading to M.S. and Ph.D. degrees in Mechanical Engineering and in Aerospace Engineering. An M.S. in Manufacturing Engineering is also offered.

Department Mission

The mission of the Mechanical and Aerospace Engineering Department is to educate the nation’s future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological innovation while fostering academic excellence and scholarly learning in a collegial environment.

Undergraduate Program Objectives

The aerospace engineering and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: (1) to teach students how to apply their rigorous undergraduate education to creatively solve technical problems facing society and (2) to prepare them for successful and productive careers or graduate studies in mechanical or aerospace or other engineering fields and/or further studies in other fields such as medicine, business, and law.

Undergraduate Study

The Aerospace Engineering and Mechanical Engineering majors are designated capstone majors. Within their capstone courses, Aerospace Engineering students are exposed to the conceptual and design phases for aircraft development and produce a structural design of a component, such as a lightweight aircraft wing. Mechanical Engineering students work in teams in their capstone courses to propose, design, analyze, and build a mechanical or electromechanical device. Graduates of both programs should be able to apply their knowledge of mathematics, science, and engineering in technical systems; design a system, component, or process to meet desired needs; function as productive members of a team; identify, formulate, and solve engineering problems; and communicate effectively, both orally and in writing.

Aerospace Engineering B.S.

Capstone Major

The aerospace engineering program is concerned with the design and construction of various types of fixed-wing and rotary-wing (helicopters) aircraft used for air transportation and national defense. It is also concerned with the design and construction of spacecraft, the exploration and utilization of space, and related technological fields. Aerospace engineering is characterized by a very high level of technology. The aerospace engineer is likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts. Meeting these demands requires the imaginative use of many disciplines, including fluid mechanics and aerodynamics, structural mechanics, materials and aeroelasticity, dynamics, control and guidance, propulsion, and energy conversion.
Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 94; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, 150P, 154S, 155 or 161A or 169A, 157A, 157S, 166A, 171A, 182A; two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104 — if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper division course or courses from the department — except for Mechanical and Aerospace Engineering 156A — or, by petition, from outside the department); three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Mechanical and Aerospace Engineering 154A, 154B); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 105D, 131A, 131AL, C132A, 133A, 133AL, 150C, C150G, 150P, 150R, 153A, 155, 157A, 161A, 161B, 163A, 166C, M168, 169A, 171B, 172, 174, C175A, CM180, CM180L, 181A, 182B, 182C, 184, 185, C186, C187L. For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission, see Graduate Programs, page 23. The following introductory information is based on the 2012-13 edition of Program Requirements for UCLA Graduate Degrees: Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

The Department of Mechanical and Aerospace Engineering offers the Master of Science (M.S.) degree in Manufacturing Engineering, Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Aerospace Engineering, and Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Mechanical Engineering. All new M.S. and Ph.D. students who are pursuing an M.S. degree in the Mechanical and Aerospace Engineering Department must meet with their advisers in their first term at UCLA. The goal of the meeting is to discuss the students’ plans for satisfying the M.S. degree requirements. Students should obtain an M.S. planning form from the department Student Affairs Office and return it with their advisers’ signature by the end of the first term.

Aerospace Engineering M.S. and Mechanical Engineering M.S.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor's degree may not be applied toward a graduate degree at UCLA. The courses should be selected so that the breadth requirements and the requirements at the graduate level are met. The breadth requirements are only applicable to students who do not have a B.S. degree from an ABET-accredited aerospace or mechanical engineering program.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or 150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 250C, 250D, 250F, 253B, 254A, 255B, 256F, 263B, 269D, or 271B.
The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

**Mechanical Engineering**

**Breadth Requirements.** Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D or 183.

**Graduate-Level Requirement.** Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 231A, 231B, 231C, 250A, 250B, 255A, M256A, M256B, M269A, C271A, 294, or 297. The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

**Comprehensive Examination Plan**

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic advisor, is established to administer the examination. Students may, in consultation with their advisor and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three mechanical and aerospace engineering graduate courses. Contact the department Student Affairs Office for more information.

**Thesis Plan**

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

**Manufacturing Engineering M.S.**

**Areas of Study**

Consult the department.

**Course Requirements**

Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor's degree may not be applied toward a graduate degree at UCLA. Choices may be made from the following major areas:

**Undergraduate Courses.** No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

**Upper Division Courses.** Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 163A, M168, 174, 183, 184, 185.

**Graduate Courses.** Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, CM280A, 293, 294, 295A, 295B, 296A, 296B, 297.

**Additional Courses.** The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design M226B, M227B, 227D; Computer Science 241A, 241B; Management 240A, 240D, 241A, 241B, 242A, 242B, 243B, 243C; Mathematics 120A, 120B.

**Comprehensive Examination Plan**

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic advisor, is established to administer the examination. Students may, in consultation with their advisor and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three graduate courses. Contact the department Student Affairs Office for more information.
Thesis Plan
The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students would normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Aerospace Engineering Ph.D. and Mechanical Engineering Ph.D.

Major Fields or Subdisciplines
Dynamics; fluid mechanics; heat and mass transfer; manufacturing and design (mechanical engineering only); nanoelectromechanical/microelectromechanical systems (NEMS/MEMS); structural and solid mechanics; systems and control.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature or (2) the field represents an important research area for which there is no established major field in the department (condition 2 most often applies to recently evolving research areas or to areas for which there are too few faculty members to maintain an established major field).

Students in an ad hoc major field must be sponsored by at least three faculty members, at least two of whom must be from the department.

Course Requirements
The basic program of study for the Ph.D. degree is built around major and minor fields. The established major fields are listed above, and a detailed syllabus describing each Ph.D. major field can be obtained from the Student Affairs Office.

The program of study for the Ph.D. requires students to perform original research leading to a doctoral dissertation and to master a body of knowledge that encompasses material from their major field and breadth material from outside the major field. The body of knowledge should include (1) six major field courses, at least four of which must be graduate courses, (2) one minor field, (3) any three additional courses, at least two of which must be graduate courses, that enhance the study of the major or minor field.

The major field syllabus advises students as to which courses contain the required knowledge, and students usually prepare for the written qualifying examination (formerly referred to as the preliminary examination) by taking these courses. However, students can acquire such knowledge by taking similar courses at other universities or even by self-study.

The minor field embraces a body of knowledge equivalent to three courses, at least two of which must be graduate courses. Minor fields are often subsets of major fields, and minor field requirements are then described in the syllabus of the appropriate major field. Established minor fields with no corresponding major field can also be used, such as applied mathematics and applied plasma physics and fusion engineering. Also, an ad hoc field can be used in exceptional circumstances, such as when certain knowledge is desirable for a program of study that is not available in established minor fields.

Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, and the three additional courses mentioned above are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only).

Written and Oral Qualifying Examinations
After mastering the body of knowledge defined in the major field, students take a written qualifying (preliminary) examination covering this knowledge. Students must have formally admitted to the Ph.D. program or admitted subject to completion of the M.S. degree by the end of the term following the term in which the examination is given. The examination must be taken within the first two calendar years from the time of admission into the Ph.D. program. Students must be registered during the term in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student’s major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field.

After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years from the time of admission into the Ph.D. program. The nature and content of the examination are at the discretion of the doctoral committee but include a review of the dissertation prospectus and may include a broad inquiry into the student’s preparation for research.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department.

Fields of Study

Dynamics
Features of the dynamics field include dynamics and control of physical systems, including spacecraft, aircraft, helicopters, industrial manipulators; analytical studies of control of large space structures; experimental studies of electromechanical systems; and robotics.

Fluid Mechanics
The graduate program in fluid mechanics includes experimental, numerical, and theoretical studies related to a range of topics in fluid mechanics, such as turbulent flows, hypersonic flows, microscale and nanoscale flow phenomena, aeroacoustics, bio fluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, bio fluid mechanics, hypersonics, reactive flow, fluid stability, turbulence, and experimental methods.

Heat and Mass Transfer
The heat and mass transfer field includes studies of convection, radiation, conduction, evaporation, condensation, boiling and two-phase flow, chemically reacting and radiating flow, instability and turbulent flow, reactive flows in porous media, as well as transport phenomena in support of microscale and nanoscale thermosciences, energy, bioMEMS/NEMS, and microfabrication/nanofabrication.

Manufacturing and Design
The program is developed around an integrated approach to manufacturing and design. It includes study of manufacturing and design aspects of mechanical systems,
material behavior and processing, robotics and manufacturing systems, CAD/CAM theory and applications, computational geometry and geometrical modeling, composite materials and structures, automation and digital control systems, microdevices and nanodevices, radio frequency identification (RFID), and wireless systems.

**Nanoelectromechanical/ Microelectromechanical Systems**
The nanoelectromechanical/microelectromechanical systems (NEMS/MEMS) field focuses on science and engineering issues ranging in size from nanometers to millimeters and includes both experimental and theoretical studies covering fundamentals to applications. The study topics include microscience, top-down and bottom-up nanofabrication/microfabrication technologies, molecular fluidic phenomena, nanoscale/microscale material processing, biomolecular signatures, heat transfer at the nanoscale, and system integration. The program is highly interdisciplinary in nature.

**Structural and Solid Mechanics**
The solid mechanics program features theoretical, numerical, and experimental studies, including fracture mechanics and damage tolerance, micromechanics with emphasis on technical applications, wave propagation and nondestructive evaluation, mechanics of composite materials, mechanics of thin films and interfaces, analysis of coupled electro-magneto-thermomechanical material systems, and ferroelectric materials. The structural mechanics program includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aerelasticity, fluid structure interaction, computational transonic aerelasticity, biomechanics with applications ranging from whole organs to molecular and cellular structures, structural optimization, finite element methods and related computational techniques, structural mechanics of composite material components, structural health monitoring, and analysis of adaptive structures.

**Systems and Control**
The program features systems engineering principles and applied mathematical methods of modeling, analysis, and design of continuous- and discrete-time control systems. Emphasis is on modern applications in engineering, systems concepts, feedback and control principles, stability concepts, applied optimal control, differential games, computational methods, simulation, and computer process control. Systems and control research and education in the department cover a broad spectrum of topics primarily based in aerospace and mechanical engineering applications. However, the Chemical and Biomolecular Engineering and Electrical Engineering Departments also have active programs in control systems, and collaboration across departments among faculty members and students in both teaching and research is common.

**Ad Hoc Major Fields**
The ad hoc major fields program has sufficient flexibility that students can form academic major fields in their area of interest if the proposals are supported by several faculty members. Previous fields of study included acoustics, system risk and reliability, and engineering thermodynamics. Nuclear science and engineering, a former active major field, is available on an ad hoc basis only.

**Facilities**
The Mechanical and Aerospace Engineering Department has a number of experimental facilities at which both fundamental and applied research is being conducted. More information is at http://www.mae.ucla.edu.

**Active Materials Laboratory**
The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, magnetostrictive, shape memory alloys, and fiber optic sensors. The laboratory has manufacturing facilities to fabricate magnetostrictive composites and thin film shape memory alloys. Testing active material systems is performed on one of four servo-hydraulic load frames. All of the load frames are equipped with thermal chambers, solenoids, and electrical power supplies.

**Autonomous Vehicle Systems Instrumentation Laboratory**
The Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. The AVSIL contains a hardware-in-the-loop (HIL) simulator designed and built at UCLA that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the Interstate Electronics Corporation GPS Satellite Constellation Simulator. The UCLA flight control software can be modified to accommodate satellite-system experiments using real-time software, GPS receivers, and inter-vehicle modem communication.

**Computational Fluid Dynamics Laboratory**
The Computational Fluid Dynamics Laboratory has several medium-size Beowolf Linux clusters for numerical simulation of transitional, turbulent, and high speed compressible flows, with and without reaction, as well as the sound that they produce. The laboratory has access to supercomputers (large clusters of parallel processors on various platforms) at NSF PACI Centers and DoD High-Performance Computing Centers.

**Energy and Propulsion Research Laboratory**
The Energy and Propulsion Research Laboratory is engaged in research and education pertaining to the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research is directed toward the development of fundamental engineering knowledge as well as tools for solving critical national problems, with current applications to improved engine efficiency, reduced emissions, alternative fuels, and advanced high-speed air breathing and rocket propulsion systems.

**Fluid Mechanics Research Laboratory**
The Fluid Mechanics Research Laboratory includes a full line of water tunnels equipped with various advanced transducers (MEMS-based sensors and actuators, particle image anemometer, laser Doppler anemometer, hot-wire anemometers) and data acquisition systems.

**Fusion Science and Technology Center**
The Fusion Science and Technology Center includes a number of state-of-the-art experimental facilities for conducting research in fusion engineering. The center includes experimental facilities for (1) liquid metal magnetohydrodynamic fluid flow dynamics and heat transfer, (2) thick and thin liquid metal systems exposed to intense particle and heat flux loads, and (3) metallic and ceramic material thermo-mechanics.
Heat Transfer Laboratories
The Heat Transfer Laboratories are used for experimental research on heat transfer and thermal hydraulics. The laboratories are equipped with several flow loops, high-current power supplies, high-frequency induction power supplies, holography and hot-wire anemometry setups, and state-of-the-art data acquisition systems.

Materials Degradation Characterization Laboratory
The Materials Degradation Characterization Laboratory is used for the characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and for research on fracture mechanics and ultrasonic nondestructive evaluation.

Micro and Nano Manufacturing Laboratory
The Micro and Nano Manufacturing Laboratory is equipped with a fume hood, wafer saw, wire bonder, electroplating setup including vacuum capability, various microscopes including fluorescent and 3D scanning, various probe stations including RF capability, vibration-isolation and optical tables, environmental chambers, drop dispensing system, various instruments (e.g., impedance analyzer), and full video imaging capability. It is used for MEMS and nano research, and complements the HSSEAS Nanoelectronics Research Facility, the 8,500-square-foot, class 100/1000 clean room where most micromachining steps are carried out.

Microsciences Laboratory
The Microsciences Laboratory is equipped with advanced sensors and imaging processors for exploring fundamental physical mechanisms in MEMS-based sciences.

Multifunctional Composites Laboratory
The Multifunctional Composites Laboratory provides equipment necessary to develop multifunctional nanocomposites and explore their applications by integrating technologies involving composites, nanomaterials, information, functional materials, biomimetics, and concurrent engineering. Some of the equipment in the laboratory includes an autoclave, a flame winder, a resin transfer molding machine, a waterjet cutting machine, a stereo lithography machine, a laminated object manufacturing machine, a coordinate measuring machine, a field emission scanning electron microscope, a scanning probe microscope, an FTIR, a rheometer, a thermal analysis system, an RCL analyzer, a microdielectric analyzer, an X-ray radiography machine, and a variety of mechanical testing machines.

Multiscale Thermosciences Laboratory
The Multiscale Thermosciences Laboratory (MTSL) is equipped with a state-of-the-art atomic force microscope, an inverted optical microscope with fluorescence attachment, an ultra-long depth-of-field digital microscope, an infrared camera, a cryostat, an RF frequency lock-in amplifier, semiconductor lasers, a wide variety of electronic instruments/DAQ systems, and a quad-core workstation with 32GB RAM.

Plasma and Beam Assisted Manufacturing Laboratory
The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for the purpose of processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power D.C. supplies (400kw), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

Plasma Propulsion Laboratory
The Plasma Propulsion Laboratory includes vacuum systems, power supplies, and diagnostics for the study of plasma propulsion devices.

Subsonic Wind Tunnel
The 3 x 3-foot Subsonic Wind Tunnel is used for research on unsteady aerodynamics on oscillating airfoils and instruction.

Thin Films, Interfaces, Composites, Characterization Laboratory
The Thin Films, Interfaces, Composites, Characterization Laboratory consists of a Nd:YAG laser of 1 Joule capacity with three ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 Kp-capacity servohydraulic biaxial test frame, walk-in freezer, polishing and imaging equipment for microstructural characterization for measurement and control study of thin film interface strength, NDE using laser ultrasound, de-icing of structural surfaces, and characterization of composites under multiaxial stress state.

Faculty Areas of Thesis Guidance
Professors
Mohamed A. Abdou, Ph.D. (Wisconsin, 1973)
Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermomechanics, thermal hydraulics, fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-material interactions; blankets and high heat flux components; experiments, modeling and analysis.
Oddvar O. Bendiksen, Ph.D. (UCLA, 1980)
Classical and computational aerelasticity, structural dynamics and unsteady aerodynamics.
Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models, fatigue characterization of piezoelectric ceramics, magnetostrictive composites, characterizing shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally evaluating damage in composites.
Ivan Catton, Ph.D. (UCLA, 1966)
Heat transfer and fluid mechanics, transport phenomena in porous media, nucleonics heat transfer and thermal hydraulics, natural and forced convection, thermal/hydrodynamic stability, turbulence.
Jiun-Shyan U-Si Chen, Ph.D. (Northwestern, 1989)
Finite element methods, mesh free methods, large deformation mechanics, inelasticity, contact problems, structural dynamics.
Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems.
Vijay K. Dhir, Ph.D. (Kentucky, 1972)
Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling.
Mobile Internet, web-based product design, wireless and collaborative engineering, CAD/visualization.
Nasr M. Ghoniem, Ph.D. (Wisconsin, 1977)
Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy.
James S. Gibson, Ph.D. (U. Texas, Austin, 1975)
Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation.
Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanics and characterization of composite materials, ice mechanics.
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, microelectromechanical systems (MEMS), bionano technologies, biomolecular sensor arrays, control of...
Tetsuya Iwasaki, Ph.D. (Purdue, 1993)  
Clinical systems, augmented reality, and image processing  

Robert T. M'Closkey, Ph.D. (Caltech, 1995)  
Analytical, numerical, and computational fluid dynamics, high-speed flow across horizontal cylinders  

Ann R. Karagozian, Ph.D. (Caltech, 1982)  
Computational fluid dynamics, computational fluid dynamics, numerical simulations  

Computational fluid dynamics, high-speed flow across horizontal cylinders  

Microelectromechanical systems; micro/nano fabrication technologies; structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)  

J. John Kim, Ph.D. (Stanford, 1978)  
Laminar and turbulent boundary layers, equilibrium and nonequilibrium free shear flows, boundary layer stability, mixing layers, vortex dynamics  

Thermal convection, thermocapillary convection, stability of shear flows, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics  

Michaél A. Melkanooff, Ph.D. (UCLA, 1955)  
Programmable languages, data structures, database and relational models, interaction systems, robotics, computer-aided design and manufacturing, numerical-controlled machinery  

Anthony F. Mills, Ph.D. (U.C. Berkeley, 1965)  
Convective heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers  

D. Lewis Mingori, Ph.D. (Stanford, 1966)  
Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles  

Peter A. Monkewitz, Ph.D. (E.T.H., Federal Institute of Technology, Zurich, 1977)  
Fluid mechanics, internal acoustics and noise produced by turbulent jets  

Philip F. O'Brien, M.S. (UCLA, 1949)  
Radiative transfer and satellite remote sensing  

Laurent Pilon, Ph.D. (Purdue, 2002)  
Convective heat and mass transfer, condensation, stability of shear flows, stratified and rotating flows, ablation and transpiration cooling, perforated plate heat exchangers  

Industrial engineering, environmental design, thermal and luminescent engineering systems  

David Okrent, Ph.D. (Harvard, 1951)  
Fast reactors, reactor physics, nuclear reactor safety, nuclear fuel element behavior, risk-benefit studies, nuclear environmental safety, fusion reactor theory  

Lucien A. Schmitt, Jr., M.S. (MIT, 1950)  
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components  

Owen I. Smith, Ph.D. (U.C. Berkeley, 1977)  
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition  

Richard Stern, Ph.D. (UCLA, 1964)  
Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics  

Russell A. Westmann, Ph.D. (UC Berkeley, 1962)  
Thermal sciences, system design  

Amiya K. Chatterjee, Ph.D. (UCLA, 1976)  
Computational structural and solid mechanics, nuclear methods development  

H. Pirouz Kavehpour, Ph.D. (MIT, 2003)  
Mechanical and nanoelectromechanical systems (MEMS/NEMS), magnetism, nano-bio technology  

Associate Professors  

Pei-Yu Chou, Ph.D. (U.C. Berkeley, 2005)  
BioMEMS, biophotonics, electrokinesis, optical manipulation, optoelectronic devices  

Jeff D. Eldredge, Ph.D. (Caltech, 2002)  
Numerical simulations of fluid dynamics, bioinspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vortex-based numerical methods, simulations of biophysical fluids  

Y. Sungtaek Ju, Ph.D. (Stanford, 1999)  
Heat transfer, thermodynamics, microelectromechanical and nanoelectromechanical systems (MEMS/NEMS), magnetism, nano-bio technology  

Plasma and laser processing, fusion technology research, fusion reactor component design, material property characterization  

Randalo Szilard, Ph.D. (UCLA, 1992)  
Nuclear engineering, nuclear reloader licensing, core design, core monitoring processes, nuclear methods development  

Ralph B. Dorr, Ph.D. (Harvard, 1977)  
Experimental study of subcooled flow film boiling across horizontal cylinders  

Y. Sungtaek Ju, Ph.D. (Stanford, 1999)  
Heat transfer, thermodynamics, microelectromechanical and nanoelectromechanical systems (MEMS/NEMS), magnetism, nano-bio technology  

Anna R. Karagozian, Ph.D. (Caltech, 1982)  
Structural analysis and design, composite structures, engineering management  

H. Pirouz Kavehpour, Ph.D. (MIT, 2003)  
Computational structural and solid mechanics, nuclear methods development  

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Fast reactors, reactor physics, nuclear reactor safety, nuclear fuel element behavior, risk-benefit studies, nuclear environmental safety, fusion reactor theory  

Lucien A. Schmitt, Jr., M.S. (MIT, 1950)  
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components  

Owen I. Smith, Ph.D. (U.C. Berkeley, 1977)  
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition  

Richard Stern, Ph.D. (UCLA, 1964)  
Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics  

Russell A. Westmann, Ph.D. (UC Berkeley, 1962)  
Thermal sciences, system design  

Amiya K. Chatterjee, Ph.D. (UCLA, 1976)  
Computational structural and solid mechanics, nuclear methods development  

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Mechanical and nanoelectromechanical systems (MEMS/NEMS), magnetism, nano-bio technology  

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Numerical simulations of fluid dynamics, bioinspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vortex-based numerical methods, simulations of biophysical fluids  

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Anthony F. Mills, Ph.D. (U.C. Berkeley, 1965)  
Convective heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers  

D. Lewis Mingori, Ph.D. (Stanford, 1966)  
Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles  

Peter A. Monkewitz, Ph.D. (E.T.H., Federal Institute of Technology, Zurich, 1977)  
Fluid mechanics, internal acoustics and noise produced by turbulent jets  

Philip F. O’Brien, M.S. (UCLA, 1949)  
Industrial engineering, environmental design, thermal and luminescent engineering systems  

David Okrent, Ph.D. (Harvard, 1951)  
Fast reactors, reactor physics, nuclear reactor safety, nuclear fuel element behavior, risk-bene-
102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 1A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in two and three dimensions. Impulse-momentum and work-energy relationships. Applications. Letter grading.

Mr. Klug (F,W,Sp)

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

Mr. Kavelhoun, Mr. J. Kim (F,W,Sp)

105A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Concepts of equilibrium, temperature, and reversibility; first law; concept of entropy; equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading.

Mr. Pilon (F,W,Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Concepts of equilibrium, temperature, and reversibility; first law; concept of entropy; equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading.

Mr. Ju (F,W)

107. Introduction to Modeling and Analysis of Dynamic Systems. (4) Lecture, four hours; discussion, one hour; laboratory, two hours; outside study, five hours. Enforced requisite: Computer Science 31. Engineering 100 (enforced). Introduction to modeling of physical systems, with examples of mechanical, fluid, thermal, and electrical systems. Description of these systems with a focus on impulse response, convolution, frequency response, first- and second-order system transient response analysis, and numerical solution. Nonlinear differential equation de-
scriptions with discussion of equilibrium solutions, small signal linearization, large signal response. Block diagram representation and response of inter-
connections of systems. Hands-on experiments rein-
force lecture material. Letter grading.

Mr. M'Closkey, Mr. Tsao (F,W,Sp)

131A. Intermediate Heat Transfer. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 105D (enforced). Computer Science 31. Steady conduc-
tion; two-sided, two-ended, tapered, and circular fins; buried cylinders, thick fins. Transient conduction; slabs, cylinders, products. Convection: transient, laminar pipe flow, film condensation, boundary lay-
ers, dimensional analysis, working correlation, sur-
face radiation. Two-stream heat exchangers. Ele-
ments of thermal design. Letter grading.

Ms. Lavine (F,W)

131AL. Thermodynamics and Heat Transfer Labo-
ratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 131A, and 157 or 157S. Experimental study of physical phenomena and engi-
neering systems using modern data acquisition and processing techniques. Experiments include studies of heat transfer phenomena and testing of cooling
tower, heat exchanger, and internal combustion en-
gine. Students take and analyze data and discuss physical phenomena. Letter grading.

Mr. Pilon (Not offered 2012-13)

C132A. Mass Transfer. (4) Lecture, four hours; out-
side study, eight hours. Requisites: courses 105D, 131A. Principles of mass transfer by diffusion and convection. Concepts of mass transfer: Transport in multicomponent systems. Thermal, forced, and pressure diffusion, Brownian diffusion. Analysis of evaporative and transpiration cooling, ca-
alysis, and combustion. Mass exchange: automobile catalytic converters, electrostatic precipi-
tators, filters, scrubbers, humidifiers, and cooling tow-
 ers. Concurrently scheduled with course C232A. Let-
ter grading.

Mr. Pilon (Not offered 2012-13)

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, reactive and nonreactive fluid flow systems. Letter grading.

Mr. Catton (W,Sp)

133AL. Power Conversion Thermodynamics Lab-
oratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 133A, and 157 or 157S. Experimental study of power conversion and heat transfer systems, instrumentation and equipment. Experiments include studies of thermodynamic operating characteristics of actual Brayton cycle, Rankine cycle, compressive refrigeration unit, and absorption refrigeration unit. Letter grading.

Mr. Catton (Sp)

134. Design and Operation of Thermal Hydraulic Power Systems. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Requisites: courses 133A, 133AL. Thermal hydraulic design; maintenance and operation of power systems, gas turbines, steam turbines, centrifugal refrigeration units, absorption refrigeration units, compressors, valves and piping systems, and instrumentation and control systems. Letter grading.

Mr. Catton (Not offered 2012-13)

135. Fundamentals of Nuclear Science and Engi-
neering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20A, Mathematics 33B. Review of nuclear physics, radioactivity and decay, and radiation interaction with matter. Nuclear fission and fusion processes and mass-energy conversion. Nuclear fission: diffusion and multiplication, heat transfer issues, and applications. Introduction to nuclear power plants for commercial electricity production, space power, spacecraft propulsion, and nuclear science for medical uses. Letter grading.

Mr. Abdou (W)

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 105D. Recommended: courses 131A, 133A. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, geothermal, solar, wind, and ocean, fuels, transportation, energy conserva-
tion, air and water pollution, global warming. Letter grading.

Mr. Pilon (W)

CM140. Introduction to Biomechanics. (4) (Same as Bioengineering CM140.) Lecture, four hours; dis-
cussion, two hours; outside study, six hours. Enforced requisites: courses 101, 102, 156A. Introduction to mechanism fundamentals: skeletal adap-
tations to optimize load transfer, mobility, and func-
tion. Dynamics and kinematics. Fluid mechanics ap-

Mr. Gupta (W)

150A. Intermediate Fluid Mechanics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103, 182A. Basic equations governing fluid motion. Fundamental solutions of Navier/Stokes equations. Lubrication the-
ory. Elementary potential flow theory. Boundary lay-

Mr. Eldredge, Ms. Karagozian (F,W)

150B. Aerodynamics. (4) Lecture, four hours; dis-
cussion, two hours; outside study, six hours. Requi-
sites: courses 103, 150A. Advanced aspects of po-
tential flow theory. Incompressible flow around thin airfoils (lift and moment coefficients) and wings (lift, induced drag). Gas dynamics: oblique shocks, Prandtl-Meyer expansion. Laminar subsonic and

Mr. Zhong (Sp)

150C. Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requi-
sites: courses 103, 105A. Chemical thermodynamics of ideal gas mixtures, premixed and diffusion flames, explosions and detonations, combustion chemistry, high explosives. Combustion processes in rocket, tur-
bine, and internal combustion engines; heating appli-
cations. Letter grading.

Ms. Karagozian (Not offered 2012-13)

C150G. Fluid Dynamics of Biological Systems. (4) (Formerly numbered 150D.) Lecture, four hours; discussion, two hours; outside study, nine hours. Requisites: Chemistry 20B, Mechanics of aquatic locomotion; insect and bird flight aerodynamics; pulsatile flow in circulatory syst-
em; rheology of blood; role of fluid dynamics in arterial diseases. Concur-
rently scheduled with course C250G. Letter grading.

Mr. Eldredge (Sp)

150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103A, 150A. Thermodynamic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft propulsion systems. Letter grading.

Ms. Karagozian (F)

150R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103A, 150A. Not open to students with credit for both courses 161B and 161R. Rocket propulsion concepts, including chemi-
racial rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Letter grading.

Ms. Karagozian, Mr. Wirz (Sp)

153A. Engineering Acoustics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for junior/senior engineering majors. Fundamental course in acoustics; propagation of sound; sources of sound. Design of field measurements. Estimation of jet and blade noise with design aspects. Letter grading.

Mr. Eldredge (Not offered 2012-13)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 154S. Classical preliminary design of aircraft, including weight esti-
mation, performance and stability, and control consid-
eration. Term assignment consists of preliminary de-
sign of low-speed aircraft. Letter grading.

Mr. Bendiksen (W)

154B. Design of Aircraft Structures. (4) Lecture, four hours; outside study, eight hours. Requi-
sites: courses 154A, 166A. Design of aircraft, heli-
copter, spacecraft, and related structures. External loads, internal stresses. Applied theory of thin-walled structures. Material selection, design using compos-
ite materials. Design for fatigue prevention and struc-
tural failure. Professor Field, Professor Fredericks, 
Professor Etkin, Professor Godfrey, Professor Schap-
pers. Letter grading.

Mr. Bendiksen (Sp)

154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 150A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed for design of aircraft. Effects of airplane flexibility on stability derivatives. Letter grading.

Mr. Bendiksen (F)

Mechanical and Aerospace Engineering / 103
156. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 101, 102, 103A, 105A, 105D. Structural analysis of important engineering components and structural systems. Emphasis on physical phenomena in area of strength of materials. Lecture, four hours; discussion, two hours; laboratory, six hours. Enforced requisites: courses 101, 103A, 105A, 105D. Structural analysis of important engineering components and structural systems. Emphasis on physical phenomena in area of strength of materials. Letter grading. Mr. Ghoniem, Mr. Tsao (W)

157A. Fluid Mechanics and Aerodynamics Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 150A, 150B, and 157 or 157S. Experimental investigation of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording, data analysis, signal processing, and data analysis. Letter grading. Mr. Ghoniem, F.W.Sp

157B. Aerospace Systems Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 101, 102, 103A, 105A, 105D, Electrical Engineering 100. Methods of measurement of basic physical quantities in Mechanical and Aerospace Engineering systems, as well as hands-on experience with design of experimental programs and use of modern experimental tools and techniques in field. Letter grading. Mr. Kavehpour (Sp)

158. Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 101, 102, 103A, 105A, Electrical Engineering 100. Recommended: course 157A. Fluid mechanics, general aerodynamics, and structures. Applications of primary transducers, computer-aided data acquisition, signal processing, and data analysis. Performance of experiments to enhance understanding of basic physical principles and characteristics of structural and fluid systems relevant to aerospace engineering. Letter grading. Mr. Ju (W,Sp)

161. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended preparation: courses 102, 150F, 151F. Not open to students with credit for both courses 150F and 151F. Preparation requirements for typical space missions, thermodynamics of propulsion, orbital transfer and rendezvous, problem of three bodies, and perturbation theory. Influence of Earth’s oblateness. Letter grading. Mr. Wirz (Sp)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 161B or 161B. Coverage of preliminary design, by students, of small spacecraft carrying lightweight scientific payload, flight requirements for electric power, life, and attitude stability. Students work in groups of three or four, with each student responsible primarily for one subsystem and for integration with whole. Letter grading. Mr. Wirz (Sp)

161D. Space Technology Hardware Design. (4) Lecture, two hours; laboratory, three hours; outside study, six hours. Recommended preparation: course 161B. Design, by students, of hardware with applications to space technology. Designs are then built by HSSEAS professional machine shop and tested by students. New project carried out each year. Letter grading. Mr. Wirz (Not offered 2012-13)


162D. Mechanical Engineering Design I. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisites: courses 94, 131A (or 133A), 156A (or 183), 162A (or 171A). Limited to seniors. First of two mechanical engineering capstone design courses. Courses on engineering design project management, design of thermal systems, mechanisms, mechanical systems, and mechanical components. Students work in teams to begin their two-term project, and modules include: CAD design, CAD analysis, mechatronics, and conceptual design for team project. Letter grading. Mr. Ghoniem, Mr. Tsao (W)

163A. Introduction to Computer-Controlled Mechani- cal Systems. Lecture, four hours; laboratory, six hours; outside study, seven hours. Enforced requisites: course 171A. Modeling of computer-controlled machines, including electrical and mechanical elements, mechanical elements and sensors, and overall control of electromechanical systems. Motion and command generation, servo-controller design, and computer/machine interfacing. Letter grading. Mr. Tsao (Not offered 2012-13)

166A. Analysis of Flight Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 101, 182A. Not open to students with credit for course 156A. Introduction to two-dimensional elasticity, stress-strain laws, yield and fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled cross sections: shear flow; shear-lag; combined bending torsion of thin-walled, stiffened cross sections; elastic stability; plates of plate theory; buckling of columns. Letter grading. Mr. Carman (F)

166B. Design of Composite Structures. (4) Lecture, four hours; laboratory, six hours; outside study, six hours. Enforced requisites: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, failure analysis, composite laminate design, buckling of composite components, nonisymmetrical laminates, micromechanics of composite materials. Letter grading. Mr. Carman (W)

168. Introduction to Finite Element Methods. (4) Lecture, four hours; laboratory, nine hours; discussion, six hours; outside study, seven hours. Enforced requisites: course 156A or Civil Engineering 130. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual methods, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical nonlinearities; mesh generation and postprocessing techniques; term projects with computers. Letter grading. Mr. Chen, Mr. Krug (F)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101, 102, 107. Fundamentals of vibration theory and applications. Free, forced, and transient vibration of one and two degrees of freedom systems, including damping. Normal modes, coupling, and normal coordinates. Vibration isolation devices, vibrations of continuous systems. Letter grading. Mr. Bendiksen (F)

171A. Introduction to Feedback and Control Sys- tems. Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisites: courses 101, 102, Electrical Engineering 141. Analysis and design of digital control systems. Sampling theory. Z-transforms. Discrete-time system representation. Design using classical methods: root locus, frequency response, minimum phase plants. Lecture topics supported by weekly hands-on laboratory work. Letter grading. Mr. Tsao (Sp)

172. Control System Design Laboratory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 171A. Introduction to loop shaping controller design with application to laboratory electromechanical systems. Pole-zero models of mechanical systems and performance trade-offs imposed by conflicting requirements. Constraints on sensitivity function and complementary sensitivity function imposed by non-minimum phase plants. Laboratory supervised by weekly hands-on laboratory work. Letter grading. Mr. M’Closkey (Not offered 2012-13)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Mathematics 33A. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading. Mr. Bendikson, Mr. Gupta (W)

C175A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 101, 182A. Probability spaces, random variables, stochastic processes and processes, expectation, conditional expectation, Gauss/Markov sequences, and minimum variance estimator (Kalman filter) with application. Concurrently scheduled with course C271A. Letter grading. Mr. Speyer (F)

CM180. Introduction to Micromachining and Micro- electromechanical Systems (MEMS). (4) (Same as Bioengineering CM150 and Electrical Engineering CM150.) Lecture and laboratory work; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to micromachining technologies and mi-
cro electromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM280A. Letter grading.

Mr. C.-J. Kim (F)

CM180L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM180L and Electrical Engineering M185L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM180, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM280L. Letter grading.

Mr. C.-J. Kim (F)

101A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 182A. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transforms. Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading.

Mr. Ghoniem (Not offered 2012-13)


Mr. Mal (F,W,Sp)


Mr. C.-J. Kim (W,Sp)

184. Introduction to Geometric Modeling. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: course 94, Computer Science 31. Fundamentals of parametric curve and surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transformations, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and implementation. Letter grading.

Mr. Gadh (Not offered 2012-13)

185. Introduction to Radio Frequency Identification and Its Application in Manufacturing and Supply Chain. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Requisites: Computer Science 31. Manufacturing today requires assembling of individual components into assembled products, shipping of such products, and eventually disassembling of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and assemblies of products allow them to be tracked automatically as they move and transform through manufacturing supply chain. RFID tags have memory and small CPU that allows information about product status to be written, stored, and transmitted wirelessly. Tag data can then be forwarded by reader to enterprise software by way of RFID middleware layer. Study of how RFID is being utilized in manufacturing, with focus on automotive and aerospace. Letter grading.

Mr. Gadh (Not offered 2012-13)


Mr. Chiou (Sp)

C187L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Requisites: Concurrently scheduled with course C187. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down (e.g., scanning probe microscopy) and bottom-up (e.g., nanolithography) nanofabrication, nanochip fabrication (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C287L. Letter grading.

Mr. Y. Chen (F,Sp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Special topics in mechanical and aerospace engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and graduate students taught on experimental or temporary basis, such as those taught by resident and graduate students taught on experimental or temporary basis, such as those taught by resident and graduate students taught on experimental or temporary basis. May be repeated once for credit with topic or instructor change. P/NP or letter grading.

(W,Sp)

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit. P/NP or letter grading.

M237. Fusion Engineering and Design. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Completion of a project required. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.

Mr. Abdou (W,Sp)

Graduate Courses


Mr. Pilon (Sp)

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: course 105D. Radiative properties of materials and radiative energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation transfer in absorbing, emitting, and scattering media. Applications cover laser/mater interactions in addition to traditional areas such as combustion and thermal engineering. Letter grading.

Mr. Pilon (Sp)


Mr. Catton (F)

231G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131D. Heat carriers (photons, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equations, derivation of classical laws from Boltzmann transport equations, derivation from classical laws at small scale. Letter grading.

Mr. Ju (F)


Mr. Pilon (Sp)

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 182A. Underlying physics and mathematical foundations of nuclear reactors, (fission) core design. Diffusion theory, re- actor kinetics, slowing down and thermalization, multigroup methods, introduction to transport theory. Letter grading.

Mr. Abdou (F)


Mr. Abdou (W,Sp)


Mr. Abdou (F,Sp)
250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Fundamental principles of fluid dynamics applied to study of fluid resistance. States of fluid motion discussed in order of advancing Reynolds number; wakes, boundary layers, instability, transition, and turbulent shear flows. Letter grading. Ms. Karagozian, Mr. J. Kim (Sp)

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Characteristics of turbulent flows, conservation and transport equations, statistical description of turbulent flows, scales of turbulent motion, simple turbulent flows, free-shear flows, wall-bounded flows, turbulence modeling, turbulence control. Letter grading. Mr. J. Kim

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Review of fluid mechanics and chemical thermodynamics applied to reactive systems, laminar diffusion flames, premixed laminar flames, stability, ignition, turbulent combustion, supersonic combustion. Letter grading. Ms. Karagozian

252E. Advanced Engineering Acoustics. (4) Lecture, four hours; outside study, eight hours. Advanced study of solid, fluid, and gas wave propagation in three-dimensional wave propagation; propagation in bound- ed media; Ray acoustics; attenuation mechanisms in fluids. Letter grading. Mr. Eldredge

253A. Special Topics in Acoustics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 182A, 182B, 252C. Special topics of current interest in advanced acoustics. Lecture and/or laboratory. Letter grading. Mr. Zhong

255A. Linear Elasticity. (4) (Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Linear elasticity. Cartesian tensors, principal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Meniscus, and Cerruti. Introduction to boundary integral equation method. Letter grading. Mr. Mal (F)

255B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Nonlinear elasticity. Principles of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermomechanics; linearization of field equations; solution of selected problems. Letter grading. Mr. Dong, Mr. Mal (W)

255C. Plasticity. (4) (Same as Civil Engineering M230C.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Classical rate-dependent plasticity; plasticity in finite strain, boundary conditions, principle of energy. Return mapping algorithms for plasticity and viscoplasticity. Finite element implementation. Letter grading.

256F. Analytical Fracture Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Review of modern fracture mechanics, elementary stress analyses; analytical and numerical methods for calculation of crack tip stress intensity factors; engineering applications in stiffened structures, pressure vessels, plates, and shells. Letter grading. Mr. Gupta

257A. Elastodynamics. (4) (Same as Earth and Space Sciences M224A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves in unbounded isotropic, anisotropic, and disisotropic solids. Half-space problems in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading. Mr. Mal (F)

258A. Topics in Micro mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materials at scales ranging from atomic through microstructure or transitional and up to continuum. Discussion of atomistic simulation methods (e.g., molecular...
dynamics, Langevin dynamics, and kinetic Monte Carlo and their applications at nanoscale. Development of dislocation dynamics: A review of computational mechanics methods in areas of nanostructure and microstructure self-organization, heterogeneous plastic deformation, material instabilities, and failure phenomena. Presentation of technical applications of various field theories and models to dislocations and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultrathin nanolayer materials), nanoindentation, smart (active) materials, nanobiengineering, and torsion. Letter grading.

Mr. Ghoniem

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assignments in research problems leading to term paper or oral presentation (possible help from guest lecturers). Letter grading.

Mr. Kavehpour

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of various fields of solid mechanics on topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability of solids. Letter grading.

Mr. Mal

260. Computational Mechanics of Solids and Structures. (4 to 8) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, and student presentations and projects in areas of computational mechanics. May be repeated for credit. S/U grading.


Mr. Klug (F)


Mr. Klug (F)

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 166C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macro analysis, including classical lamination theory, shear lag theory, concentrated cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inchworm, and bistability. Letter grading.

Mr. Carman (Sp)

263A. Analytical Foundations of Motion Controllers. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: courses 163A, 294. Theory of motion control for modern computer-controlled machines; multiaxis computer-controlled machines; machine kinematics and dynamics; multiaxis motion coordination; coordinated motion with desired speed and acceleration; jerk analysis; motion command generation and design of controllers; motion trajectory design and analysis; geometry-speed-sampling time relationships. Letter grading.

Mr. Ghoniem

263B. Spacecraft Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Recommended: course 255B. Modeling, dynamics, and stability of spacecraft; spinning and dual-spin spacecraft dynamics; spinup through resonance, spinning rocket dynamics; environmental torques; stability, and motion; reconstruction of flexible space structures. Letter grading.

Mr. Wirz


Mr. Ghoniem (W)

263D. Advanced Robotics. (4) Lecture, four hours; outside study, eight hours. Recommended preparation: courses 155, 171A, 263C. Motion planning and control of articulated dynamic systems: nonlinear joint control, experiments in joint control and multiaxis coordination, multibody dynamics, trajectory planning, motion optimization, dynamic performance and manipulator design, kinematic redundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading.

Mr. Ghoniem


Mr. Bendiksens (W)


Mr. Bendiksens

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aeroelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow induced instability and response of structural systems. Letter grading.

Mr. Bendiksens

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M230A and Electrical Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aeroelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow induced instability and response of structural systems. Letter grading.

Mr. Bendiksens

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M230A and Electrical Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aeroelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow induced instability and response of structural systems. Letter grading.

Mr. Bendiksens

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses C271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading.

Mr. Speyev


Mr. Speyev

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics include: state-dependent stochastic differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading.

Mr. Speyev

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M228A and Electrical Engineering M228A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M228A or Electrical Engineering M228A. Focus on time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading.

Mr. M'Closkey

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading.

Mr. M'Closkey

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M228A or Electrical Engineering M228A. Focus on time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading.

Mr. M'Closkey

275B. System Identification. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading.

Mr. M'Closkey

Mr. Gibson (Sp)


Mr. M'Closkey

277. Advanced Digital Control for Mechatronic Systems. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 171B, M270A. Digital signal processing and control analysis of mechatronic systems. System inversion-based digital control algorithms and robustness properties. Youla parameterization of stabilizing control-
279. Dynamics and Control of Biological Oscilla-
tions. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 107, M270A. Analysis and design of oscillating bio-
ter logic control systems that generate coordinated osc-
illations. Topics include neuronal information pro-
cessing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, epito-
mal gaits (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Tsao

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Principles and performance of micro transduc-
ners. Applications of using unique properties of micro trans-
duction such as various types of force, position, and vibra-
neering problems. Associated signal processing re-
quirements for these applications. Letter grading. Mr. Ho

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 105A, 105D, 182A. Introduction to fundamental physical phenomena occurring at interfaces and ap-
lication of their knowledge to engineering problems. Fundamental concepts in interfacial phenomena, in-
cluding surface tension, surfactants, interfacial ther-
odynamics, interfacial forces, interfacial hydrody-
amics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emul-
sions, microelectromechanical systems, and bio-
logical systems. Letter grading. Mr. Pilon

286. Applied Optics. (4) Lecture, four hours; dis-
cussion, two hours; study, six hours. Requisites: Physics 1C. Fundamental principles of optical systems. Geometric optics and aberration theory. Dif-
fraction and interference. Propagation of light, Snell’s law, and Huygen princi-
ple. Refraction and reflection. Plane waves, spherical waves, and image formation. Total internal reflection. Polarization, polarizers, and wave-plates. Lenses and aberrations, lens laws and formation of images, reso-
lution and primary aberrations. Simple optical instru-
ments, still cameras, shutters, apertures. Design of telescopes, microscopes, Fourier optics projection system design. Interference, Young’s slit experiment and fringe visibility. Michelson interferometer, multiple-
beam interference and thin film coatings. Diffraction theory. Fresnel zone plate. Fiber optics, waveguides and modes, fi-
bre coupling, types of fibre: single and multimode. Concurrently scheduled with course C186. Letter grading. Mr. Chiou

287. Nanoscience and Technology. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Basic science issues in micro domain. Topics include micro fluid science, microscale heat transfer, me-
chanical behavior of microstructures, as well as dy-
amics and control of micro devices. Letter grading. Mr. Ho, Mr. C-J. Kim (F)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Material-
als Science 104, and an engineer-
ning of laser microscopic fabrication of advanced ma-
terials, including semiconductors, metals, and insula-
tors. Topics include fundamentals in laser interactions with advanced materials, laser-thermal issues (therma-

287L. Nanoscale Fabrication, Characteriza-
tion, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Multidisciplinary course that introduces labora-
tory techniques of nanoscale fabrication, characteriza-
tion, and biodetection. Basic physical principles of physical science, quantum mechanics, chemical bonding and nano-
structures, top-down and bottom-up (self-assembly) nanofabri-
cation; nanocharacterization; nanomaterials for biology. Concurrently scheduled with course C187L. Letter grading. Mr. Y. Chen (Sp)

292. Microelectromechanical Systems (MEMS) (M.

293. Quality Engineering in Design and Manufac-
turing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 174. Quality engineering concepts and approaches. Taguchi methods of robust design and one-line control. Quality loss function, signal-to-noise ratio, and or-
thogonal arrays. Parametric design of products and process production. Tolerance design. Online qual-
ity control systems. Decision making in quality engi-
neering. Letter grading. Mr. Ghoniem

294. Computational Geometry for Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 184. Computa-
tional geometry for design and manufacturing, with
inside emphasis on curve and surface theory, geo-
metric modeling of curves and surfaces, B-splines and NURBS, composite curves and surfaces, comput-
ing methods for surface design and manufacture, and current research topics in computational geome-
try for CAD/CAM systems. Letter grading. Mr. Ghoniem

295. Computer-Aided Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requi-
sites: courses 94, 184. Exploration of advanced state-of-the-art concepts in Internet-based collabora-
tive design, including software environments to con-
duct designers over Internet, networked variable me-
dia graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mo-
bile devices based systems, and multidisciplinary de-
sign collaboration and software tools to support it. Letter grading. Mr. Gadh

296. Thermochromic Processing of Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 183. Thermodynamics, heat and mass transfer, principles of material processing; phase equilibria and transitions, transport mecha-

297. Composites Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisites: course 186C, Materials Science 151. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/
compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading. Mr. Ghoniem
298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate mechanical and aerospace engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

M299A. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M297 and Electrical Engineering M248S.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading.

495. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, four hours. Preparation: appointment as teaching assistant in department. Seminar on communication of mechanical and aerospace engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading.

596. Directed Individual or Tutorial Studies. (2 to 8) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Reading and preparation for M.S. comprehensive examination. S/U grading.

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Supervised independent research for M.S. candidates, including thesis prospectus. S/U grading.

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

Master of Science in Engineering Online Program

UCLA
7440 Boelter Hall
Box 951594
Los Angeles, CA 90095-1594
(310) 825-6542
fax: (310) 825-3081
http://msol.ucla.edu

Christopher S. Lynch, Ph.D., Director

Scope and Objectives

The primary purpose of the Master of Science in Engineering online degree program is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed. The training and education that the program offers are of significant importance and usefulness to engineers, their employers, California, and the nation. It is at the M.S. level that engineers have the opportunity to learn a specialization in depth, and those engineers with advanced degrees may also renew and update their knowledge of the technology advances that continue to occur at an accelerating rate.

The M.S. program is addressed to those highly qualified employed engineers who, for various reasons, do not attend the on-campus M.S. programs and who are keenly interested in developing up-to-date knowledge of cutting-edge engineering and technology.

Graduate Study

For information on graduate admission, see Graduate Programs, page 23.

The following introductory information is based on the 2012–13 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmqrintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

M.S. in Engineering Online Program

Course Requirements

The program consists of nine courses that make up a program of study. At least five courses must be at the 200 level, and one must be a directed study course. The latter course satisfies the University of California requirement for a capstone event (in the on-campus program the requirement is covered by a comprehensive examination or a thesis); the directed study course consists of an engineering design project that is better suited for the working engineer/computer scientist.

The program is structured in a manner that allows employed engineers/computer scientists to complete the requirements at a part-time pace (e.g., one 100/200-level course per term). Courses are scheduled so that the program can be completed within two academic years plus one additional term.

Advanced Structural Materials

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Director; jyang@seas.ucla.edu

The program provides students with a broad knowledge of advanced structural materials. Courses cover fundamental concepts of science and engineering of lightweight advanced metallic and composite materials, fracture mechanics, damage tolerance and durability, failure analysis and prevention, nondestructive evaluation, structural integrity and life prediction, and design of aerospace structures. Students are required to complete a project on a topic related to structural materials.

Aerospace Engineering

Xiaolin Zhong, Ph.D. (Mechanical and Aerospace Engineering), Director; xiaolin@seas.ucla.edu

The main objective of the program is to provide students with broad knowledge of the major technical areas of aerospace engineering to fulfill the current and future needs of the aerospace industry. Major technical areas include aerodynamics and computational fluid dynamics (CFD), systems and control, and structures and dynamics. Courses cover fundamental concepts of science and engineering of aerodynamics, compressible flow, computational aerodynamics, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, and dynamics of structures. Through a graduate
course, students also gain skills in the development and application of CFD codes for solving practical aerospace problems.

If students have taken Mechanical and Aerospace Engineering 150B, 154B, and 171B or the equivalent at their undergraduate institutions, they can take other online-offered courses, approved by the area director, as substitute courses. In addition, students are required to complete a project on a topic related to the three major areas of this program.

**Computer Networking**

Mario Gerla, Ph.D. (Computer Science), Director; gerla@cs.ucla.edu

Three undergraduate elective courses complement the basic background of the undergraduate electrical engineering or computer science degree with concepts in security, sensors, and wireless communications. The graduate courses expose students to key applications and research areas in the network and distributed systems field. Two required graduate courses cover the Internet and emerging sensor embedded systems. The electives probe different applications domains, including wireless mobile networks, security, network management, distributed P2P systems, and multimedia applications.

**Electronic Materials**

Ya-Hong Xie, Ph.D. (Materials Science and Engineering), Director; yhx@ucla.edu

The electronic materials program provides students with a knowledge set that is highly relevant to the semiconductor industry. The program has four essential attributes: theoretical background, applied knowledge, exposure to theoretical approaches, and introduction to the emerging field of microelectronics, namely organic electronics. All faculty members have industrial experience and are currently conducting active research in these subject areas.

**Integrated Circuits**

Dejan Markovic, Ph.D. (Electrical Engineering), Director; dejan@ee.ucla.edu

The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signaling and synchronization, VLSI signal processing, and communication system design. Summer courses are not yet offered in this program; therefore it cannot currently be completed in two calendar years.

**Manufacturing and Design**

Daniel C.H. Yang, Ph.D. (Mechanical and Aerospace Engineering), Director; dyang@seas.ucla.edu

The manufacturing and design program covers a broad spectrum of fundamental and advanced topics, including mechanical systems, digital control systems, microdevices and nanodevices, wireless systems, failure of materials, composites, and computational geometry. The program prepares students with the higher educational background that is necessary for today’s rapidly changing technology needs.

**Mechanics of Structures**

Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Director; ajit@seas.ucla.edu

The mechanics of structures program provides students with the knowledge required for the analysis and synthesis of modern engineered structures. The fundamental concepts of linear and nonlinear elasticity, plasticity, fracture mechanics, finite element analysis, and mechanics of composites and structural vibrations are developed in a series of undergraduate and graduate courses. These concepts are then applied in solving industry-relevant problems in a number of graduate-level courses. Students develop hands-on experience in using finite element packages for solving realistic structural analysis problems.

**Signal Processing and Communications**

Kung Yao, Ph.D. (Electrical Engineering), Director; yao@ee.ucla.edu

The program provides training in a set of related topics in signal processing and communications. Students receive advanced training in multimedia systems from the fundamentals of media representation and compression through transmission of signals over communications links and networks.

**System Engineering**

Peter S. Pao, Ph.D. (Computer Science), Director; peterspao@ucla.edu

System engineering has broad applications that include software, hardware, materials, and electrical and mechanical systems. A set of four core courses is offered that form the foundation of the system engineering program. The sequence of courses is designed for working professionals who are faced with design, development, support, and maintenance of complex systems.
Schoolwide Programs, Courses, and Faculty

UCLA
6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
(310) 825-9580
http://www.engineer.ucla.edu

Professors Emeriti
Allen B. Rosenstein, Ph.D.
Bonham Spence-Campbell, E.E.

Graduate Study
For information on graduate admission to the schoolwide engineering programs and requirements for the Engineer degree and certificate of specialization, see Graduate Programs, page 23.

Faculty Areas of Thesis Guidance
Professors Emeriti
Allen B. Rosenstein, Ph.D. (UCLA, 1958)
Bonham Spence-Campbell, E.E. (Cornell, 1939)

Development of interdisciplinary engineering/social science teams and their use in planning and management of projects and systems

Lower Division Courses

10A. Introduction to Complex Systems Science. (9) (Formerly numbered M10A.) Lecture, four hours. How macroscopic patterns emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control. Such emergent order, whose explanation cannot be reduced to explanations at level of individual entities, is ubiquitous in biology and human social collectives, but also exists in certain physical processes such as earthquakes and some chemical reactions. Complexity also deals with how such systems undergo sudden changes, including catastrophic breakdowns, in absence of external force or central influence. Key aspect of biological and social collectives is their nature as complex adaptive systems, where individuals and groups adjust their behavior to external conditions. In biological and social systems, complexity science goes beyond traditional mathematics and statistics in its use of multigain computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

Mr. Bragin (F).

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

Introduction to Engineering as a professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team-based learning in three hours, with underlying current effort to increase participation of historically underrepresented groups in U.S. technological work force. Letter grading.

Mr. Wesel (F).

95. Internship Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to freshmen and sophomores. Internship studies course supervised by associate dean or designated faculty member. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be applied toward major requirements. May be repeated with new intern, with new college, or with new employer. Associate dean required. P/NP grading.

Mr. Wesel (F), Mr. Spence-Campbell (E).

98. What Students Need to Know about Careers in Engineering. (2) Seminar, two hours. Introduction to skills and aptitudes that most engineers require in their careers and description of big picture of engineering careers. Integrating framework provided to relate specific of engineering courses to real world of engineering and roadmap of extracurricular activity that strengthens skills needed to acquire good jobs and achieve career success. P/NP grading.

Mr. Silverstein (F), Mr. Spence-Campbell (E).

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

M101. Principles of Nanoscience and Nanotechnology. (4) (Same as Materials Science M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20, and Electrical Engineering 1 or Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties of nanoscale systems, stability, self-assembly, templated assembly and applications of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes. Letter grading.

Mr. Ozolins (F).

102. Synthetic Biosystems and Nanosystems Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course M101, Life Sciences 3. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems, where biological components are reengineered and rewired to perform desirable functions in both intracellular and cell-free environments. Discussion of basic technologies and systems analysis that deal with dynamic behavior, noise, and uncertainties. Design project in which students are challenged to design novel biosystems and nanosystems for non-trivial task required. Letter grading.

Mr. Liao (F).

103. Environmental Nanotechnology: Implications and Applications. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Reconciled requisites: course M101. Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental processes. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nano-materials, (2) transport, reactivity, and toxicity of nanoscale systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading.

Mr. Hoek (Sp).

911. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamental principles of micro-level (individual, firm, and industry) and macro-level (government, international) economics as they relate to technology management. How individuals, firms, and government impact successful commercialization of high technology products and services. Letter grading.

Mr. Monbouquette (F), Mr. Spence-Campbell (E).

111. Introduction to Finance and Marketing for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of finance and marketing research and practice as they impact management of technology commercialization. Internal (intrapreneurial) and external (intrapreneurship) strategies to commercialize emerging technologies. Marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, internal rate of return, return on assets, return on equity, return on investment, interest rates, cost of capital, and product, price, positioning, and promotion. Use of market research, segmentation, and forecasting in management of technological innovation. Letter grading.

Mr. Monbouquette (W).

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of entrepreneurship, finance, marketing, human resources, and accounting disciplines as they impact management of technology commercialization. Topics include intellectual property management, team building, market forecasting, and entrepreneurial finance. Students work in small teams studying technology management plans to bring new technologies to market. Students select from set of available technology concepts, many generated at UCLA, that are in need of plans for movement from laboratory to market. Letter grading.

Mr. Monbouquette (W).

113. Product Strategy. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for juniors/seniors. Introduction to current management concept of product development. Topics include product strategy, product platform, and product lines; competitive strategy, vectors of differentiation, product pricing, first-to-market versus fast-follow; growth strategy, growth through acquisition, and new ventures; product portfolio management. Case studies, class projects, group discussions, and guest lectures by speakers from industry. Letter grading.

Mr. Yao (F).

180. Engineering of Complex Systems. (4) Lecture, four hours; discussion, two to four hours; outside study, six hours. Designed for junior/senior engineering majors. Holistic view of engineering discipline, covering lifecycle of engineering, processes, and techniques used in industry today. Emphasis on systems engineering perspective in which aspects of electrical, mechanical, material, and software engineering are incorporated. Three specific case studies in communication, sensor, and processing systems included to help students understand these concepts. Special attention is paid to link material covered to engineering curriculum offered by UCLA to help students integrate and enhance their understanding of knowledge already acquired. Motivation of students to continue their learning and reinforce lifelong learning habits. Letter grading.

Mr. Wesel (W), Mr. Rojas (F).

183EW. Engineering and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisites: English Composition 3 or 3H or English as a Second Language 36. Not open for credit to students with credit for course 185EW. Limited to sophomore/junior/senior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and on development of moral and ethical values. Contemporary environmental, biological, legal, and other issues created by new technologies. Emphasis on research and writing within engineering environments. Writing and revision of about 20 pages total, including two individual technical essays and one team-written research report.
Graduate Courses

200. Program Management Principles for Engineers and Professionals. (4) Lecture; four hours; outside study, eight hours. Designed for graduate students. Practical necessary processes and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading. Mr. Welzel.

201. Systems Engineering. (4) Lecture; four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading. Mr. Welzel.

202. Reliability, Maintainability, and Supportability. (4) Lecture; four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with one to two years work experience. Integrates logistic support as a major driver of system life-cycle cost and one key element of system engineering activities. Overview of engineering disciplines critical to this function — reliability, maintainability, and supportability — and their relationships taught using probability theory. Topics also include fault detections and isolations and parts obsolescence. Discussion of 6-sigma process, one effective design and manufacturing methodology, to ensure system reliability, maintainability, and supportability. Letter grading. Mr. Welzel.

203. System Architecture. (4) Lecture; four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with B.S. degrees in engineering or science and one to two years work experience in selected domain. Art and science of architecting. Introduction to architecting methodology — paradigm and tools. Principles of architecting through analysis of architecture designs of major existing systems. Discussion of selected elements of architectural practices, such as representation models, design progression, and architecture frameworks. Examination of professionalization of system architecting. Letter grading. Mr. Welzel.

204. Trusted Systems Engineering. (4) Lecture, four hours. Trust is placed in information systems to behave properly, but cyber threats and breaches have become routine, including penetration of financial, medical, government, and national security systems. To build systems that can protect confidentiality, integrity, and availability involves more than exposing systems from network security, computer security, and cryptography, etc. One can use most secure components, and result system could still be vulnerable. Skills learned ensure that systems are architected, designed, implemented, tested, and operated for specific levels of trust. Aspects include assessing vulnerability and risk for systems, establishing protection principles, and using them as a guide to formulate system architectures; translating architecture into system design and verifying correctness of design; and constructing and following trusted development and implementation processes. Letter grading.

211. Entrepreneurship for Engineers. (4) Formerly numbered 210. Lecture, four hours. Limited to graduate engineering students. Topics in starting and developing high-tech enterprises and intended for students who wish to gain technical education with introduction to entrepreneurship. Letter grading. Mr. Abe, Mr. Cong, Mr. Welzel (W).

299. Capstone Project. (4) Activity, 10 hours. Preparation: completion of minimum of four 200-level courses in online M.S. program. Project course that satisfies UCLA final comprehensive examination requirement of M.S. online degree in Engineering. Project completed under individual guidance from UCLA Engineering faculty member who incorporates advanced knowledge learned in M.S. program of study. Letter grading. Mr. Lynch.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel (e.g., teaching assistants, undergraduate teaching assistants, etc.) who are enrolled in graduate engineering writing courses. Mentoring in group and individual meetings. Continued focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in course writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F, W, Sp) Letter grading.

473A-473B. Analysis and Synthesis of Large-Scale Systems. (3 to 5) Lecture, two and one-half hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495A. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading.

M495B. Supervised Teaching Preparation. (2) Same as English Composition M495E.) Seminar, two hours. Required of all teaching assistants for Engineering writing courses not exempt by appropriate departmental or program preparation. Training and mentoring, with focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialization on developing writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F, W, Sp) Letter grading.

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Used to record enrollment of UCLA students in courses taken under cooperative arrangements with USC. S/U grading.
Center for Domain-Specific Computing

National Science Foundation Expedition in Computing Program
Jason Cong, PhD. (Computer Science), Director; http://www.cdsc.ucla.edu

To meet ever-increasing computing needs and overcome power density limitations, the computing industry has entered the era of parallelization, with tens to hundreds of computing cores integrated into a single processor and hundreds to thousands of computing servers connected in warehouse-scale data centers. However, such highly parallel, general-purpose computing systems still face serious challenges in terms of performance, energy, heat dissipation, space, and cost. The Center for Domain-Specific Computing (CDSC) looks beyond parallelization and focuses on domain-specific customization as the next disruptive technology to bring orders-of-magnitude power-performance efficiency improvement to important application domains.

CDSC develops a general methodology for creating novel customizable architecture platforms and the associated compilation tools and runtime management environment to support domain-specific computing. The proposed domain-specific customizable computing platform includes a wide range of customizable computing elements, from heterogeneous fixed cores to coarse-grain customizable cores and fine-grain field-programmable circuit fabrics; customizable high-performance radio frequency interconnects; highly automated compilation tools and runtime management software systems for application development; and a general, reusable methodology for customizable computing applicable across different domains. By combining these critical capabilities, the goal is to deliver a supercomputer-in-a-box that is customized to a particular application domain to enable disruptive innovations in that domain. This approach is being demonstrated in several important application domains in healthcare.

The CDSC research is carried out as a collaborative effort between four universities: UCLA (lead institution), Rice University, UC Santa Barbara, and Ohio State University. The research team consists of a group of highly accomplished researchers with diversified backgrounds, including computer science and engineering, electrical engineering, medicine, and applied mathematics. CDSC offers many research opportunities for graduate students, and also provides summer research fellowship programs for high school and undergraduate students. The core funding for CDSC is provided by the National Science Foundation with a $10 million award from the 2009 Expedition in Computing Program. This program, established in 2006 by the NSF Directorate for Computer and Information Science and Engineering (CISE), provides the CISE research and education community with the opportunity to pursue ambitious, fundamental research agendas that promise to define the future of computing and information and to render great benefit to society.

Center for Embedded Networked Sensing

National Science Foundation Science and Technology Center
Deborah Estrin, Ph.D. (Computer Science), Director; http://www.cens.ucla.edu

The Center for Embedded Networked Sensing (CENS) is a major research enterprise focused on developing wireless sensing systems and applying this revolutionary technology to critical scientific and societal pursuits. In the same way that development of the Internet transformed our ability to communicate, the ever-decreasing size and cost of computing components sets the stage for detection, processing, and communication technology to be embedded throughout the physical world and, thereby, fostering a deeper understanding of the natural and built environment and, ultimately, enhancing our ability to design and control these complex systems. By investigating fundamental properties of embedded networked sensing systems, developing new technologies, and exploring novel scientific and educational applications, CENS is a world leader in unleashing the tremendous potential these systems hold. The center is a multidisciplinary collaboration among faculty, staff, and students from a wide spectrum of fields, including computer science, electrical engineering, civil and environmental engineering, biology, statistics, education and information sciences, urban planning, and theater, film, and television. CENS was established in 2002 as a National Science Foundation Science and Technology Center and is a partnership of UCLA, UC Riverside, UC Merced, USC, and Caltech. The center’s current research portfolio encompasses projects across nine technology and applications areas, examples of which include:
- development and deployment of new measurement tools and techniques to identify the sources and fates of chemical and biological pollutants in natural, urban, and agricultural watersheds and coastal zones
- development of cameras and image analysis approaches that assist scientists in making biological observations. Together, the camera and analysis systems comprise a new type of biosensor that takes measurements otherwise unobservable to humans
- harnessing the technological power of mobile phones and the ubiquitous wireless infrastructure for applications in areas as diverse as public health, environmental protection, urban planning, and cultural expression, each of which is influenced by independent personal behaviors adding up in space and time.

Center on Functional Engineered Nano Architectonics

Microelectronic Advanced Research Corporation Focus Center
Kang L. Wang, Ph.D. (Electrical Engineering), Director; Bruce S. Dunn, Ph.D. (Materials Science and Engineering), Co-Director; http://www.fena.org

Dramatic advances in nanotechnology, molecular electronics, and quantum computing are creating the potential for significant expansion of current semiconductor technologies. Researchers at UCLA make pioneering contributions to these fields through the Functional Engineered Nano Architectonics Focus Center (FENA) funded by the Semiconductor Research Association and the Department of Defense.

The term “architectonics” is derived from a Greek word meaning master builder—an apt description of the center’s researchers as they build a new generation of nano-scale materials, structures, and devices for the electronics industry.

The FENA team explores the challenges facing the semiconductor industry as the electronic devices and circuits that power today’s computers grow ever smaller. With more and more transistors and other components squeezed onto a single chip, manufacturers are rapidly approaching the physical limits posed by current chip-making processes. Researchers seek to resolve a number of issues related to post-CMOS technologies that allow them to extend semiconductor technology further into the realm of the nanoscale.

Molecularly Engineered Energy Materials Energy Frontier Research Center

U.S. Department of Energy, Office of Science, Basic Energy Sciences
Vidvuds Ozolins, Ph.D. (Materials Science and Engineering), Director

The Interdisciplinary Molecularly Engineered Energy Materials (MEEM) Energy Frontier Research Center (EFRC) was established in
2009 and brings together several faculty across the UCLA campus in close collaboration with scientists and faculty at the Department of Energy’s National Renewable Energy Laboratory, Eastern Washington University, the University of Kansas, and UC Berkeley, MEEM has active research programs on organic solar cells, electrochemical supercapacitors, and materials for carbon capture. MEEM focuses on materials that are inherently inexpensive (such as polymers, oxides, and metal-organic frameworks), can be easily assembled from intelligently de-signed building blocks (molecules, nanoparticles, and polymers), and have the potential to deliver transformative economic benefits in comparison with current crystalline- and polycrystalline-based energy technologies.

A great deal of the center’s research is aimed at understanding the basic science issues in energy-related materials phenomena. These advances will enable rational design, efficient synthesis, and effective deployment of novel materials for energy applications. As global energy demands continue, the center’s work will be essential in helping to make alternative and renewable energy a viable resource for the 21st century.

**Named Data Networking Project**

National Science Foundation Future Internet Architecture (FIA) Program

Lixia Zhang, Ph.D. (Computer Science), Principal Investigator; http://www.named-data.net

While the Internet has far exceeded expectations, it has also stretched initial assumptions, often creating tussles that challenge its underlying communication model. Users and applications operate in terms of content, making it increasingly limiting and difficult to conform to IPs requirement to communicate by discovering and specifying location. To carry the Internet into the future, a conceptually simple yet transformational architectural shift is required, from today’s focus on where—addresses and hosts, to what—the content that users and applications care about.

This project investigates a new Internet architecture called Named Data Networking (NDN). NDN capitalizes on strengths, and addresses weaknesses, of the Internet’s current host-based, point-to-point communication architecture in order to naturally accommodate emerging patterns of communication. By mapping data instead of their location, NDN transforms data into a first-class entity. The current Internet secures the data container. NDN secures the contents, a design choice that de-couples trust in data from trust in hosts, enabling several radically scalable communication mechanisms such as automatic caching to optimize bandwidth. The project studies the technical challenges that must be addressed to validate NDN as a future Internet architecture: routing scalability, fast forwarding, trust models, network security, content protection and privacy, and fundamental communication theory. The project uses end-to-end testbed deployments, simulation, and theoretical analysis to evaluate the proposed architecture, and is developing specifications and prototype implementations of NDN protocols and applications.

**Smart Grid Energy Research Center**

Raj Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director; http://smartgrid.ucla.edu

The UCLA Smart Grid Energy Research Center (SMERC) performs research, creates innovations, and, demonstrates advanced wireless/communications, Internet, and sense-and-control technologies to enable the development of the next generation of the electric utility grid—the Smart Grid. SMERC also provides thought leadership through partnership between utilities, renewable energy companies, technology providers, electric vehicle and electric appliance manufacturers, DOE research labs, and universities, so as to collectively work on vision, planning, and execution toward a grid of the future. The Smart Grid of the future would allow integration of renewable energy sources, reduce losses, improve efficiencies, increase grid flexibility, reduce power outages, allow for competitive electricity pricing, allow for integration of electric vehicles, and overall become more responsive to market, consumer, and societal needs. SMERC is currently working on the topics of automated demand response, electric vehicle integration (G2V and V2G), microgrids, distributed renewable integration, storage integration into microgrids, cybersecurity, and consumer behavior.

**Western Institute of Nanoelectronics**

A Nanoelectronics Research Initiative National Institute of Excellence

Kang L. Wang, Ph.D. (Electrical Engineering), Director; http://win-nano.org

The Western Institute of Nanoelectronics (WIN), one of the world’s largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically-needed innovations in semiconductor technology. A National Institute of Excellence, WIN leverages what are considered the best interdisciplinary nanoelectronics talents in the world to explore and develop advanced research devices, circuits, and nanosystems with performance beyond conventional CMOS devices. The pioneering new technology of spintronics relies on the spin of an electron to carry information, and holds promise in minimizing power consumption for next-genera

tion electronics. As rapid progress in the miniaturization of semiconductor electronic devices leads toward chip features smaller than 100 nanometers in size, researchers have had to begin exploring new ways to make electronics more efficient. Today’s devices, based on CMOS standards, cannot get much smaller and still function effectively. Information-processing technology has so far relied on charge-based devices, ranging from vacuum tubes to million-transistor microchips. Conventional electronic devices simply move these electric charges around, ignoring the spin on each electron. Spintronics aims to put that extra spin action to work—effectively cor-
ralling electrons into one smooth chain of motion.

**Wireless Health Institute**

Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical Engineering), Majid Sarrafzaden, Ph.D. (Computer Science), Co-Directors; http://www.wirelesshealth.ucla.edu

Advances in engineering and computer science are enabling the design of powerful home and mobile technologies that can augment functional independence and daily activities of people with physical impairments, disabilities, chronic diseases, and the accumulative impairments associated with aging. These home-health and mobile-health technologies can serve as monitoring devices of health and activity, feedback reinforcement for risk factor management, and outcome measures for individual care and large clinical trials. The Wireless Health Institute believes that tiny sensors—including accelerometers, gyroscopes, force transducers, and visual and sound recorders worn on the body and in clothing—will become essential components for the delivery of health care and health maintenance. Sensors created by micro- and nano-technologies will simplify communications with health providers seamlessly over Internet and WIFI transmission using telephones and other convenient devices. To pursue these applications, our collaboration includes the highly ranked UCLA schools of Medicine, Nursing, Engineering and Applied Science, and Management, the Clinical Transla
tional Science Institute for medical research, the Ronald Reagan UCLA Medical Center, and faculty from many departments on campus.
# B.S. in Aerospace Engineering Curriculum

## Freshman Year

### 1st Quarter
- Chemistry and Biochemistry 20A — Chemical Structure ........................................... 4
- Mathematics 31A — Differential and Integral Calculus ........................................... 4

### 2nd Quarter
- Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory ........................................... 7
- Mathematics 31B — Integration and Infinite Series ........................................... 4

## Sophomore Year

### 1st Quarter
- Mathematics 32B — Calculus of Several Variables ........................................... 4
- Physics 1C — Electrodynamics, Optics, and Special Relativity ........................................... 5
- Physics 4BL — Electricity and Magnetism Laboratory ........................................... 2
- HSSEAS GE Elective* ......................................................................................... 5

### 2nd Quarter
- Materials Science and Engineering 104 — Science of Engineering Materials ........................................... 4
- Mathematics 33A — Linear Algebra and Applications ........................................... 4
- Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials ........................................... 4
- Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics ........................................... 4

## Junior Year

### 1st Quarter
- Electrical Engineering 100 — Electrical and Electronic Circuits ........................................... 4
- Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies ........................................... 4
- Mechanical and Aerospace Engineering 182A — Mathematics of Engineering ........................................... 4
- HSSEAS GE Elective* ......................................................................................... 4

### 2nd Quarter
- Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems ........................................... 4
- Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics ........................................... 4
- Mechanical and Aerospace Engineering 157S — Basic Aerospace Engineering Laboratory ........................................... 4
- HSSEAS GE Elective* ......................................................................................... 4

## Senior Year

### 1st Quarter
- Mechanical and Aerospace Engineering 150P — Aircraft Propulsion Systems ........................................... 4
- Mechanical and Aerospace Engineering 154S — Flight Mechanics, Stability, and Control of Aircraft ........................................... 4
- Mechanical and Aerospace Engineering 155 (Intermediate Dynamics) or 161A (Introduction to Astronautics) or 169A (Introduction to Mechanical Vibrations) ........................................... 4
- Mechanical and Aerospace Engineering 166A — Analysis of Flight Structures ........................................... 4

### 2nd Quarter
- Mechanical and Aerospace Engineering 154A — Preliminary Design of Aircraft ........................................... 4
- Aerospace Engineering Elective† ......................................................................................... 4
- HSSEAS Ethics Course ......................................................................................... 4
- Technical Breadth Course* ......................................................................................... 4

### 3rd Quarter
- Mechanical and Aerospace Engineering 154B — Design of Aerospace Structures ........................................... 4
- Mechanical and Aerospace Engineering 157A — Fluid Mechanics and Aerodynamics Laboratory ........................................... 4
- HSSEAS GE Elective* ......................................................................................... 5
- Technical Breadth Course* ......................................................................................... 4

**TOTAL** 187

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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).

† A total of 9 units of aerospace engineering electives (two courses) is required.
# B.S. in Bioengineering Curriculum

**FRESHMAN YEAR**

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<thead>
<tr>
<th>Quarter</th>
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<tr>
<td><strong>1st Quarter</strong></td>
<td>Bioengineering 10 — Introduction to Bioengineering</td>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<td>Physics 1A or 1AH — Mechanics</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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**SOPHOMORE YEAR**

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<td>Physics 1C or 1CH — Electrodynamics, Optics, and Special Relativity</td>
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<td>Bioengineering 100 — Bioengineering Fundamentals</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>HSSEAS GE Elective*</td>
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**JUNIOR YEAR**

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<td>Bioengineering 120 — Biomedical Transducers</td>
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<td>Life Sciences 23L — Introduction to Laboratory and Scientific Methodology</td>
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<td>Bioengineering 110 — Biotransport and Bioreaction Processes</td>
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<td>Bioengineering 176 — Principles of Biocompatibility</td>
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**SENIOR YEAR**

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<td>Bioengineering 177B — Bioengineering Capstone Design II</td>
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<td>Bioengineering 180 — System Integration in Biology, Engineering, and Medicine I</td>
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<td><strong>TOTAL</strong></td>
<td><strong>187</strong></td>
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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
** Satisfies the HSSEAS ethics requirement.
† Electives include Bioengineering C101, CM102, CM103, C104, C105, C131, CM140, CM145, C147, CM150, CM150L, C170, C171, CM178, C179, 180L, 181L, 199 (8 units maximum).
# B.S. in Chemical Engineering Curriculum

## FRESHMAN YEAR

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<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<td>Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Computer Science 31 — Introduction to Computer Science I</td>
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<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B/4BL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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## SOPHOMORE YEAR

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<th>Quarter</th>
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<tr>
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<td>Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Chemical Engineering 102A — Thermodynamics I</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Chemical Engineering 102B — Thermodynamics II</td>
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<td>Mathematics 33B — Differential Equations</td>
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<th>Quarter</th>
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<td>Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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<td>Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tr>
<td>1st</td>
<td>Chemical Engineering 104B — Chemical and Biomolecular Engineering Laboratory II</td>
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<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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**Total:** 186

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Chemical Engineering

## Biomedical Engineering Option Curriculum

### FRESHMAN YEAR

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<tr>
<th>Quarter</th>
<th>Course</th>
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<td>Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering</td>
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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Computer Science 31 — Introduction to Computer Science I</td>
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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 104A — Chemical and Biomedical Engineering Laboratory I</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Chemical Engineering

## Biomolecular Engineering Option Curriculum

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<td>Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Life Sciences 2 — Cells, Tissues, and Organs</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Life Sciences 3 — Introduction to Molecular Biology</td>
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<td>Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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### SENIOR YEAR

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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Chemical Engineering
## Environmental Engineering Option Curriculum

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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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### SOPHOMORE YEAR

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<td>Chemical Engineering 102A — Thermodynamics I</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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### JUNIOR YEAR

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<td>Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I</td>
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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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<td>Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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**TOTAL**: 190

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## B.S. in Chemical Engineering

### Semiconductor Manufacturing Engineering Option Curriculum

#### FRESHMAN YEAR

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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I</td>
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**Total:** 190

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### B.S. in Civil Engineering Curriculum

**FRESHMAN YEAR**

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**JUNIOR YEAR**

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**SENIOR YEAR**

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**TOTAL** 188, 189, or 190

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).

† Must include required courses for two of the major field areas listed on page 46.
# B.S. in Computer Science Curriculum

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## SOPHOMORE YEAR

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## TOTAL

186

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Computer Science and Engineering Curriculum

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**TOTAL** 188

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Electrical Engineering Curriculum

**FRESHMAN YEAR**

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**SOPHOMORE YEAR**

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**SENIOR YEAR**

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**TOTAL**

188

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See page 74 for a list of approved pathways.
# B.S. in Electrical Engineering

## Biomedical Engineering Option Curriculum

### FRESHMAN YEAR

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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1A — Mechanics</td>
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### SOPHOMORE YEAR

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<th>Quarter</th>
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<th>Units</th>
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<td>Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>Electrical Engineering 3 — Introduction to Electrical Engineering</td>
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<td>Electrical Engineering 10 — Circuit Theory I</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>Electrical Engineering 102 — Systems and Signals</td>
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<td>Electrical Engineering 103 — Applied Numerical Computing</td>
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### JUNIOR YEAR

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<td>Electrical Engineering 131A — Probability</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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<td>Electrical Engineering 115A — Analog Electronic Circuits I</td>
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### SENIOR YEAR

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<td>Mathematics 132 — Complex Analysis for Applications</td>
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<td>Pathway Course (Electrical Engineering 176 — Photonics in Biomedical Applications or Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics)†</td>
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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See page 75 for the biomedical engineering pathway.
B.S. in Electrical Engineering
Computer Engineering Option Curriculum

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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Literature</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<td>Computer Science 33 — Introduction to Computer Organization</td>
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<tr>
<td>Electrical Engineering 3 — Introduction to Electrical Engineering</td>
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<tr>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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| SOPHOMORE YEAR                                                        |       |
| 1st Quarter                                                          |       |
| Mathematics 32B — Calculus of Several Variables                      | 4     |
| Mathematics 33A — Linear Algebra and Applications                    | 4     |
| Physics 4AL — Mechanics Laboratory                                   | 2     |
| HSSEAS GE Elective*                                                  | 5     |
| 2nd Quarter                                                          |       |
| Electrical Engineering 1 — Electrical Engineering Physics I          | 4     |
| Electrical Engineering 10 — Circuit Theory I                        | 4     |
| Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems | 4 |
| Mathematics 33B — Differential Equations                             | 4     |
| 3rd Quarter                                                          |       |
| Electrical Engineering 102 — Systems and Signals                    | 4     |
| Electrical Engineering 103 — Applied Numerical Computing            | 4     |
| Mathematics 132 — Complex Analysis for Applications                 | 4     |
| Physics 4BL — Electricity and Magnetism Laboratory                   | 2     |

| JUNIOR YEAR                                                          |       |
| 1st Quarter                                                          |       |
| Computer Science 35L — Software Construction Laboratory             | 2     |
| Electrical Engineering 101 — Engineering Electromagnetics           | 4     |
| Electrical Engineering 110 — Circuit Analysis II                     | 4     |
| Electrical Engineering 113 — Digital Signal Processing              | 4     |
| Electrical Engineering 131A — Probability                            | 4     |
| 2nd Quarter                                                          |       |
| Electrical Engineering 2 — Physics for Electrical Engineers         | 4     |
| Electrical Engineering 110L — Circuit Measurements Laboratory       | 2     |
| Electrical Engineering 115A — Analog Electronic Circuits I          | 4     |
| Statistics 105 — Statistics for Engineers                           | 4     |
| 3rd Quarter                                                          |       |
| Electrical Engineering 115C — Digital Electronic Circuits           | 4     |
| HSSEAS Ethics Course                                                | 4     |
| HSSEAS GE Elective*                                                  | 4     |
| Pathway Course (Electrical Engineering 132A — Introduction to Communication Systems or Computer Science M117 — Computer Networks: Physical Layer)† | 4 |

| SENIOR YEAR                                                          |       |
| 1st Quarter                                                          |       |
| HSSEAS GE Elective*                                                  | 5     |
| Pathway Course (Computer Science 131 — Programming Languages or 132 — Compiler Construction or 180 — Introduction to Algorithms and Complexity)† | 4 |
| Technical Breadth Course*/Pathway Laboratory Course†                 | 6     |
| 2nd Quarter                                                          |       |
| Electrical Engineering M116C or Computer Science M151B — Computer Systems Architecture | 4 |
| Pathway Course (Computer Science 111 — Operating Systems Principles)† | 4     |
| Technical Breadth Course*/HSSEAS GE Elective*                        | 9     |
| 3rd Quarter                                                          |       |
| Electrical Engineering 132B (Data Communications and Telecommunication Networks) or Computer Science 118 (Computer Network Fundamentals) | 4 |
| Pathway Design Course†                                                | 4     |
| Technical Breadth Course*/HSSEAS GE Elective*                        | 9     |

**TOTAL** 189

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See page 75 for the computer engineering pathway.
# B.S. in Materials Engineering Curriculum

## FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Materials Science and Engineering 10 — Freshman Seminar: New Materials</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<th>Course Title</th>
<th>Units</th>
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<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 101 (Statics and Dynamics) or Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)</td>
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<td>Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>3rd</td>
<td>Computer Science 31 — Introduction to Computer Science I</td>
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<td>Materials Science and Engineering 30L — Physical Measurement in Materials Engineering</td>
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## JUNIOR YEAR

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<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Laboratory</td>
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<td>Materials Science and Engineering 150 — Phase Relations in Solids</td>
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<td>Materials Science and Engineering 120 — Physics of Materials</td>
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<td>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>Materials Science and Engineering 143A — Mechanical Behavior of Materials</td>
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<td>Materials Science and Engineering 132 — Structure and Properties of Metallic Alloys</td>
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## SENIOR YEAR

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<td>Mechanical and Aerospace Engineering 181A (Complex Analysis and Integral Transforms) or 182A (Mathematics of Engineering)</td>
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<td>Materials Science and Engineering 150 — Introduction to Polymers</td>
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<td>Materials Science and Engineering 140 — Materials Selection and Engineering Design</td>
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**TOTAL** 185 or 186

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).

† See counselor in 6426 Boelter Hall for details.
# B.S. in Materials Engineering

## Electronic Materials Option Curriculum

### FRESHMAN YEAR

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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Mathematics 32B — Calculus of Several Variables</td>
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<td>Electrical Engineering 10 — Circuit Theory I</td>
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<td>Materials Science and Engineering 130 — Phase Relations in Solids</td>
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<td>Electrical Engineering 101 — Engineering Electromagnetics</td>
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<td>Materials Science and Engineering 120 (Physics of Materials) or Electrical Engineering 2 (Physics for Electrical Engineers)</td>
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<td>Materials Science and Engineering 122 — Principles of Electronic Materials Processing</td>
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<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
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<td>Materials Science and Engineering 121/121L — Materials Science of Semiconductors/Laboratory</td>
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<td>Electronic Materials Elective†</td>
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<tr>
<td>2nd Quarter</td>
<td>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<tr>
<td></td>
<td>Electronic Materials Elective†</td>
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<tr>
<td></td>
<td>Electronic Materials Laboratory Course†</td>
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<td>Technical Breadth Course*</td>
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<tr>
<td>3rd Quarter</td>
<td>Materials Science and Engineering 140 — Materials Selection and Engineering Design</td>
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<td>Electronic Materials Electives (2)†</td>
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<td>Electronic Materials Laboratory Course†</td>
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**TOTAL** 187 or 188

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See counselor in 6426 Boelter Hall for details.
## B.S. in Mechanical Engineering Curriculum

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<th>Year</th>
<th>Course</th>
<th>Units</th>
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</thead>
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<td><strong>FRESHMAN YEAR</strong>&lt;br/&gt;1st Quarter</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
<td>4</td>
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<tr>
<td></td>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<tr>
<td></td>
<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory.</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
<td></td>
<td>Physics 1A — Mechanics</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science 31 — Introduction to Computer Science I</td>
<td>4</td>
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<tr>
<td></td>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td></td>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>Physics 4AL — Mechanics Laboratory</td>
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<tr>
<td><strong>SOPHOMORE YEAR</strong>&lt;br/&gt;1st Quarter</td>
<td>Mathematics 32B — Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 94 — Introduction to Computer-Aided Design and Drafting</td>
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<td></td>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>2nd Quarter</td>
<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td></td>
<td>Mathematics 33A — Linear Algebra and Applications</td>
<td>4</td>
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<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials</td>
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<td>Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics</td>
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<tr>
<td>3rd Quarter</td>
<td>Mathematics 33B — Differential Equations</td>
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<td>Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies</td>
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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics.</td>
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<tr>
<td><strong>JUNIOR YEAR</strong>&lt;br/&gt;1st Quarter</td>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 105D — Transport Phenomena</td>
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<td>Mechanical and Aerospace Engineering 162A — Introduction to Mechanisms and Mechanical Systems</td>
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<td>Mechanical and Aerospace Engineering 182A — Mathematics of Engineering</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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<td>Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics)</td>
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<td>Mechanical and Aerospace Engineering 157 — Basic Mechanical Engineering Laboratory</td>
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<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>Mechanical and Aerospace Engineering 156A — Advanced Strength of Materials</td>
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<td>Mechanical and Aerospace Engineering 183 — Introduction to Manufacturing Processes</td>
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<td>Mechanical Engineering Elective</td>
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<tr>
<td><strong>SENIOR YEAR</strong>&lt;br/&gt;1st Quarter</td>
<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems</td>
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<td>HSSEAS Ethics Course</td>
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<td>HSSEAS GE Elective*</td>
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<td>Technical Breadth Course*</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 162D — Mechanical Engineering Design I</td>
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<td>HSSEAS GE Electives (2)*</td>
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<td>Mechanical and Aerospace Engineering 162E — Mechanical Engineering Design II</td>
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<td>HSSEAS GE Elective*</td>
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<td>Technical Breadth Course*</td>
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<td><strong>TOTAL</strong></td>
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<td>185</td>
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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
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<th>Spring 2013</th>
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<tr>
<td>First day for continuing students to check URSA at <a href="http://www.ursa.ucla.edu">http://www.ursa.ucla.edu</a> for assigned enrollment appointments</td>
<td>June 6</td>
<td>October 31</td>
<td>January 30, 2013</td>
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<tr>
<td>URSA enrollment appointments begin</td>
<td>June 18</td>
<td>November 13</td>
<td>February 11</td>
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<tr>
<td>Registration fee payment deadline</td>
<td>September 20</td>
<td>December 20</td>
<td>March 20</td>
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<tr>
<td>QUARTER BEGINS</td>
<td>September 24</td>
<td>January 2, 2013</td>
<td>March 27</td>
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<tr>
<td>Instruction begins</td>
<td>September 27</td>
<td>January 7</td>
<td>April 1</td>
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<tr>
<td>Last day for undergraduates to ADD courses with per-course fee through URSA</td>
<td>October 19</td>
<td>January 25</td>
<td>April 19</td>
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<tr>
<td>Last day for undergraduates to DROP nonimpacted courses without a transcript notation (with per-transaction fee through URSA)</td>
<td>October 26</td>
<td>February 1</td>
<td>April 26</td>
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<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP) with per-transaction fee through URSA</td>
<td>November 9</td>
<td>February 15</td>
<td>May 10</td>
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<tr>
<td>Instruction ends</td>
<td>December 7</td>
<td>March 15</td>
<td>June 7</td>
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<td>Final examinations</td>
<td>December 10-14</td>
<td>March 18-22</td>
<td>June 10-14</td>
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<td>QUARTER ENDS</td>
<td>December 14</td>
<td>March 22</td>
<td>June 14</td>
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<td>HSSEAS Commencement</td>
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<td>June 15</td>
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<tr>
<td>Academic and administrative holidays</td>
<td>November 12</td>
<td>January 21</td>
<td>March 29</td>
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<td>November 22-23</td>
<td>February 18</td>
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<td>December 24-25</td>
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<td>December 31-</td>
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<td>January 1</td>
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<tr>
<td>Winter campus closure</td>
<td>December 26-28</td>
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### Admission Calendar

<table>
<thead>
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<th>Fall 2012</th>
<th>Winter 2013</th>
<th>Spring 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filing period for undergraduate applications (file with UC Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)</td>
<td>November 1-30, 2011</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Last day to file application for graduate admission or readmission with complete credentials and application fee, with Graduate Admissions/Student and Academic Affairs, 1255 Murphy Hall, UCLA, Los Angeles, CA 90024-1428</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
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<tr>
<td>Last day to file Undergraduate Application for Readmission form at 1113 Murphy Hall (late applicants pay a late fee)</td>
<td>August 15</td>
<td>November 25</td>
<td>February 15</td>
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