Since it welcomed its first students in 1945, the UCLA Henry Samueli School of Engineering and Applied Science has been at the forefront of advanced interdisciplinary research and engineering education. 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, for major contributions to the development of technologies underlying mobile devices, and for many other activities that have led to new breakthroughs and changed the way we interact with the world around us.

Our faculty members and their 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-funded Center for Translational Applications of Nanoscale Multiferroic Systems, SRC Focus Center on Function Accelerated nanoMaterial Engineering, NRI Western Institute of Nanoelectronics, DOE-funded Center for Moleularly Engineered Energy Materials, NSF Center for Domain-Specific Computing, Smart Grid Energy Research Center, Wireless Health Institute, and NSF 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 26 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
ANNOUNCEMENT
OCTOBER 1, 2013

UNIVERSITY OF CALIFORNIA,
LOS ANGELES
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 from 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 hearing, and (5) file complaints with the U.S. Department of Education.

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) to be released as "public information" must complete the UCLA FERPA Restriction Request form available from the Registrar's Office, 1113 Murphy Hall, 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) to be released as "public information" must complete the UCLA FERPA Restriction Request form available from the Registrar's Office, 1113 Murphy Hall.

Every effort has been made to ensure the accuracy of the information presented in the Announcement of the

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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.

Cover: Artist’s rendering of the new UCLA Henry Samueli School of Engineering and Applied Science Engineering VI building now under construction. Groundbreaking took place on October 26, 2012.
Henry Samueli School of Engineering and Applied Science

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Benjamin M. Wu, D.D.S., Ph.D., Professor and Chair, Bioengineering 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 lead prominent careers as elected officials and 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 41,340 students enrolled in 128 undergraduate and 197 graduate degree programs. Nearly one in every 140 Californians holds a UCLA degree.

UCLA is ranked 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 Translational Applications of Nanoscale Multiferroic Systems (TANMS) strives to revolutionize development of consumer electronics by engineering materials that optimize energy efficiency, size, and power output on the small scale. The Focus Center on Function Accelerated nanoMaterial Engineering (FAME) aims to revolutionize semiconductor technologies by developing new nanoscale materials and structures that take advantage of properties unavailable at larger scales. The Western 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 (CDSIC) 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 sense-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 has 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 schoolwide 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 22. 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
Traugott 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 engineering, medicine, and basic sciences, bioengineering has emerged and established itself internationally as an engineering discipline in its own right. Such an interdisciplinary education is necessary to develop a quantitative engineering approach to tackle complex medical and biological problems, as well as to invent and improve the ever-evolving experimental and computational tools that are required in this engineering approach. 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 the basic sciences. Rigorously trained bioengineers are in demand in research institutions, academia, and industry. Their careers may follow a bioengineering concentration, but the ability of bioengineers to cut across traditional boundaries will facilitate their innovation in new areas.

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, nanoengineering/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 wastewater 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 other industries for assignments based on their 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 is 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 metallurgy 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 additional coursework which includes five to eight electrical engineering courses.

In order to enter a career in research and development of new materials (such as new energy devices), an M.S. or Ph.D. degree is desirable.

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, fluid 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. Graduates 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.
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5531 Boelter Hall
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Civil and Environmental Engineering Department
5731 Boelter Hall
http://cee.ucla.edu

Computer Science Department
4732 Boelter Hall
http://cs.ucla.edu

Electrical Engineering Department
58-121 Engineering IV
http://www.ee.ucla.edu

Materials Science and Engineering Department
3111 Engineering V
http://www.seas.ucla.edu/ms/

Mechanical and Aerospace Engineering Department
48-121 Engineering IV
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Continuing Education in Engineering
542 UNEX
http://www.uclaextension.edu

Engineering and Science Career Services
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http://career.ucla.edu

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Graduate Diversity, Inclusion and Admissions Office
1248 Murphy Hall
http://www.grad.ucla.edu/gasaa/admissions/applicants.htm

Financial Aid Office
A123J Murphy Hall
http://www.fao.ucla.edu

Registrar’s Office
1105 Murphy Hall
http://www.registrar.ucla.edu

Dashew Center for International Students and Scholars
106 Bradley Hall
http://www.internationalcenter.ucla.edu

Summer Sessions
1147 Murphy Hall
http://www.summer.ucla.edu

University of California
Office of the President–Admissions
http://admission.universityofcalifornia.edu
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 undergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoasa.ucla.edu), the SEASnet 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 NanoSystems 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 11 million volumes, and nearly 112,000 serial titles are received regularly. Nearly 53,000 serials and databases are electronically available through the UCLA Library Catalog, which is linked to the library’s homepage at http://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. The library also provides laptop checkout, three group study rooms, a presentation rehearsal studio, and a research commons for collaborative projects.

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 well over ten 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. 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 backend 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 two instructional computer labs with 200 Windows 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 Adobe professional and Microsoft Office (MCCA) software at no charge through the HSSEAS download service. Abaqus, Autodesk, and Dreamscape programs offer additional software at no charge to all UCLA students. Ansys offers a student version of its software for a very low fee.

UCLA’s Office of Information Technology (OIT) 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 UNIX, 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

Varaz Shahmirian, Ph.D., Director
Rachel Khoshbin, Ph.D., Program Director

The UCLA Extension (UNEX) Department of Engineering and Technology (540 UNEX, 10995 Le Conte Avenue) provides one of the nation’s largest selections of continuing engineering education programs. A short course program of 150 annual offerings draws participants from around the world for two- to four-day intensive programs. Many of these short courses are also offered on-site at companies and government agencies; see https://www.uclaextension.edu/shortcourses/. The acclaimed Technical Management Program holds its 86th offering in September 2013 and
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 UCHIP pay lower co-pays for prescriptions filled at the Ashe Center pharmacy. UCHIP 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 UCHIP withdraws with a less than 100% refund, UCHIP 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 UCHIP 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) 704-9660, 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 UCHIP 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 an e-mail to shshttpB@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 UCLAs 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 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

Annual UCLA student fees shown for 2013-14 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 stu-
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://housing.ucla.edu. Newly admitted students are sent UCLA Housing, which describes costs, locations, and eligibility for both private and UCLA-sponsored housing.

### 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 2012-13, HSSEAS awarded more than 95 undergraduate scholarship awards totaling more than $370,000. 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 students.) pay nonresident supplemental tuition. See the UCLA General Catalog appendix or the UCLA Registrar's website residence section at http://www.registrar.ucla.edu/residence/index.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.

### 2013-14 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES

<table>
<thead>
<tr>
<th>Fees</th>
<th>Undergraduate Students</th>
<th>Academic Master's Students</th>
<th>Academic Doctoral Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resident</td>
<td>Nonresident</td>
<td>Resident</td>
</tr>
<tr>
<td>Student Services Fee</td>
<td>972.00</td>
<td>972.00</td>
<td>972.00</td>
</tr>
<tr>
<td>Tuition</td>
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<td>Undergraduate Students Ass. Fee</td>
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<td>Green Initiative Fee</td>
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<td>PLEDGE Fee</td>
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<td>Graduate Students Ass. Fee</td>
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<td>Graduate Writing Center Fee</td>
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<td>Ackerman Student Union Fee</td>
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<td>Ackerman/Kershoff Seismic Fee</td>
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<td>Wooden Center Fee</td>
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<td>Student Programs, Activities, and Resources Complex Fee</td>
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<tr>
<td>Student Health Insurance Plan (UCSHIP)</td>
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<td>Course Materials and Services Fee</td>
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<td>varies, see course listings</td>
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<td>Nonresident Supplemental Tuition</td>
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<td>Document Fee</td>
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<td>New student total mandatory fees</td>
<td>$14,392.37</td>
<td>$14,392.37</td>
<td>$14,392.37</td>
</tr>
</tbody>
</table>

*For undergraduate students choosing UCSHIP with the dental option, the annual fee is $1,800.70.

**Beginning with the first academic term following advancement to doctoral candidacy, nonresident supplemental tuition for graduate students is reduced by 100% for a maximum of three years including nonregistered time periods.
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 institutions. Students who file a FAFSA are automatically considered for a Pell Grant.

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, A129J 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 2013-14 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 A129J 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 2013 for information on 2014-15 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

**Broadcom Fellowship.** Electrical Engineering Department; supports doctoral students who have passed the preliminary examination and who are doing research which explores new possibilities in state-of-the-art 22-nm CMOS technology

**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

**Intel Fellowship.** Department of Mechanical and Aerospace Engineering; supports doctoral students

**Les Knesel Scholarship Fund.** Department of Materials Science and Engineering; supports master's or doctoral students in ceramic engineering

**Guru Krupa Foundation Fellowship.** Department of Electrical Engineering; supports graduate students who received their undergraduate degrees in electrical engineering from top Indian Institutes of Technology (IIT)

**T.H. Lin Graduate Fellowship.** Department of Civil and Environmental Engineering; supports study in the area of structures
Living Spring Fellowship. Department of Electrical Engineering; supports graduate students with electrical engineering degrees from National Taiwan University, National Tsing Hua University (Taiwan) or National Chiao Tung University (Taiwan).

Microsoft Fellowship. Supports doctoral study in computer science.

National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) Fellowships. Supports study in engineering and science to highly qualified individuals from communities where human capital is virtually untapped.

Qualcomm Innovation Fellowship. Supports doctoral students across a broad range of technical research areas based on Qualcomm core values of innovation, execution, and teamwork.

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.

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

UCLA HSSEAS Electrical Engineering Fellowship funded by Qualcomm Technologies, Inc. Department of Electrical Engineering; supports doctoral students performing research in the broad areas of interests to Qualcomm within the wireless paradigm.

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. Cota-Robles, 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 advisers 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.

**Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS):** The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) brings together critical expertise in physics, chemistry, materials science, and engineering to enable rapid advancement and application of multiferroic technologies to next-generation electromagnetic (EM) devices. Its goal is to create a synergistic environment that fosters fundamental studies on magnetism control through application of an electric field while providing a pathway to commercial endeavors. Its unique needs include diverse participant characteristics that encompass how we think, how we do things, and our humanity—including but not limited to age, color, culture, disability, diversity of thought, ethnicity, gender, geographic and national origin, language, life experience, perspective, race, religion, sexual identity, socioeconomic status, and technical expertise—aimed to increase creativity and innovation.

The center’s workforce is composed of researchers who span a wide range of disciplines from chemical to mechanical engineering, and an educational spectrum from K-12 and undergraduate students to post-doctoral scholars, including those who work with industries and national laboratories focused on multiferroic systems.

TANMS’ vision is to move from diversity and inclusion advocate to active leader in the ERC community, and provide an educational pathway from cradle to career for the nation’s best and brightest, fully representative and inclusive of the talents of every community. TANMS recognizes diversity as a national imperative to take specific actions by its leadership to source and include a complete talent pool, especially those critically underrepresented populations, and all its population segments and characteristics, in TANMS’ academic leadership, technical workforce, and efforts to develop the next generation of engineers, scientists, and entrepreneurs in multiferroic systems.

TANMS is a multi-university partnership between lead institution UCLA and partners California State University Northridge, Cornell University, UC Berkeley, and Switzerland’s Edgenössisches Technische Hochschule. CEED directs the TANMS program component, supports undergraduates placed in research laboratories, and coordinates recruitment of undergraduates from other universities. CEED brings teacher-student teams to UCLA to conduct summer research and gain exposure to entrepreneurship.

**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 scholar-ships. 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 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.

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.uclasoales.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 resume book to help women students find jobs and presents a career day for women high school students. See http://www.uclasoales.com/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.

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

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, outstanding students are recognized for their academic achievement and exemplary record of contributions to the school. Recipients are acknowledged in the HSSEAS annual commencement program as well as by campuswide announcement. 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 profession, 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 study.

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, 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 the ADA and 504 Compliance Coordinator, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 825-1514, TTY (310) 206-3349. See http://www.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.ucla.edu/ucophore/coordrev/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://wwwsexualharassment.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 interven-
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/aos/toc.html) presently prohibit a variety of conduct by students which, in certain contexts, may be regarded as harassment or intimidation.

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 undergraduate minors in Bioinformatics and 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. C.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, bioengineering, 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 had 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 Examinations

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Examinations with scores of 3, 4, or 5. Students with AP Examination credit may exceed the 213-unit maximum by the amount of this credit. AP Examination credit for freshmen entering Fall Quarter 2013 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 Examination 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 UCLA’s English Composition 3 and a second UC-transferable English composition course

Transfer applicants may complete courses in addition to those above that satisfy degree requirements. Engineering and computer science courses appropriate for each major may be found at http://www.assist.org.
All units and course equivalents to AP Examinations are lower division. If an AP Examination 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 Examination</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, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, 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></td>
<td>4 or 5</td>
<td>4 units (may petition for Chemistry 20A) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Science (A Test)</td>
<td>3, 4, 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></td>
<td>4 or 5</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></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></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</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></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, 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, 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, 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></td>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, 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, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Course</td>
<td>Units</td>
<td>Description</td>
<td>Application</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------</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>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 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 5 (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 (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 excess 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 (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>

**Lower Division Courses in Other Departments**
- Chemistry and Biochemistry 20A, Chemical Structure (4 units)
- Chemistry and Biochemistry 20B, Chemical Energetics and Change (4 units)
- Chemistry and Biochemistry 20L, General Chemistry Laboratory (3 units)
- English Composition 3, English Composition, Rhetoric, and Language (5 units)
- Mathematics 31A, Differential and Integral Calculus (4 units)
- Mathematics 31B, Integration and Infinite Series (4 units)
- Mathematics 32A, 32B, Calculus of Several Variables (4 units each)
- Mathematics 33A, Linear Algebra and Applications (4 units)
- Mathematics 33B, Differential Equations (4 units)
- Physics 1A, Physics for Scientists and Engineers: Mechanics (5 units)
- Physics 1B, Physics for Scientists and Engineers: Oscillations, Waves, Electric and Magnetic Fields (5 units)
- Physics 1C, Physics for Scientists and Engineers: Electrodynamics, Optics, and Special Relativity (5 units)
- Physics 4AL, Physics Laboratory for Scientists and Engineers: Mechanics (2 units)
- Physics 4BL, Physics Laboratory for Scientists and Engineers: Electricity and Magnetism (2 units)

The courses in chemistry, mathematics, and physics are those required as preparation for majors in these subjects. Transfer students should select equivalent courses required for engineering or physical sciences majors.

**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 183 and 190, depending on the program. The maximum allowed is 213 units.

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. Grade point averages are not rounded up.

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– 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 Examinations 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
- Philosophical and Linguistic Analysis
- Visual and Performance Arts Analysis and Practice

The aim of courses in this area is to provide perspectives and intellectual skills necessary to comprehend and think critically about our situation in the world as human beings. In particular, the courses provide the basic means to appreciate and evaluate the ongoing efforts of humans to explain, translate, and transform their diverse experiences of the world through
such media as language, literature, philosophical systems, images, sounds, and performances. The courses introduce students to the historical development and fundamental intellectual and ethical issues associated with the arts and humanities and may also investigate the complex relations between artistic and humanistic expression and other facets of society and culture.

Foundations of Society and Culture
Two 5-unit courses, one from each subgroup:
- Historical Analysis
- Social Analysis

The aim of courses in this area is to introduce students to the ways in which humans organize, structure, rationalize, and govern their diverse societies and cultures over time. The courses focus on a particular historical question, societal problem, or topic of political and economic concern in an effort to demonstrate how issues are objectified for study, how data is collected and analyzed, and how new understandings of social phenomena are achieved and evaluated.

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 M166/Environmental Health Sciences M166:
- 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/.

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.

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 courses 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 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 Examinations
Some portions of Advanced Placement (AP) Examination 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.

Repetition of Courses
For undergraduate students who repeat a total of 16 units or less, only the most recently earned letter grades and grade points are computed in the grade-point average (GPA). After repeating 16 units, the GPA is based on all letter grades assigned and total units attempted. The grade assigned each time a course is taken is permanently recorded on the transcript.

1. To improve the grade-point average (GPA), students may repeat only those courses in which they receive a grade of C- or lower; NP or U grades may be repeated to gain unit credit. Courses in which a letter grade is received may not be repeated on a P/ NP or S/U basis. Courses originally taken on a P/NP or S/U basis may be repeated on the same basis or for a letter grade.

2. Repetition of a course more than once requires the approval of the College or school or the dean of the Graduate Divi-
sion and is granted only under extraordinary circumstances.

3. Degree credit for a course is given only once, but the grade assigned each time the course is taken is permanently recorded on the transcript.

4. There is no guarantee that in a later term a course can be repeated (such as in cases when a course is deleted or no longer offered). In these cases students should consult with their academic counselor to determine if there is an alternate course that can be taken to satisfy a requirement. The alternate course would NOT count as a repeat of the original course.

**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 admitted to UCLA prior to Fall Quarter 2012 use the HSSEAS 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 majors 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 2013-14 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 3.861 or better) for summa cum laude, the next five percent (GPA of 3.760 or better) for magna cum laude, and the next ten percent (GPA of 3.605 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 3.861 grade-point average for summa cum laude, a 3.760 for magna cum laude, and a 3.605 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.
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

Biomedical instrumentation

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

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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

Biomedical instrumentation

Molecular cellular tissue therapeutics

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
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) 267-4985
fax: (310) 794-5956
e-mail: bioeng@ea.ucla.edu
http://www.bioeng.ucla.edu

Benjamin M. Wu, D.D.S., Ph.D., Chair
Daniel T. Kamei, Ph.D., Vice Chair

Professors
Denise Aberle, M.D.
Mark S. Cohen, Ph.D., in Residence
Ian A. Cook, M.D.
Linda L. Demer, M.D., Ph.D.
Timothy J. Deming, Ph.D.
James Dunn, M.D., Ph.D.
Robin L. Garrell, Ph.D.
Warren S. Grundfest, M.D., FACS
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor of Aeronautics)
Dean Ho, Ph.D.
Bahram Jalali, Ph.D.
Chang-Jin Kim, Ph.D.
Wentai Liu, Ph.D.
Cun-Yu Wang, D.D.S., Ph.D.
Gerald G. Wong, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Yang Yang, Ph.D.

Professor Emeritus
Edward R.B. McCabe, M.D., Ph.D. (Mellie Executive Endowed Professor Emeritus of Pediatrics)

Associate Professors
Pei-Yu Chiu, Ph.D.
Dino Di Carlo, Ph.D.
Daniel T. Kamei, Ph.D.
Aydogan Ozcan, Ph.D.
Jacob J. Schmidt, Ph.D.

Assistant Professors
Daniel B. Ennis, Ph.D., in Residence
Andrea M. Kasko, Ph.D.
Howard Winet, Ph.D.

Adjunct Professor
Bill J. Tawil, M.B.A., Ph.D.

Adjunct Associate Professor
Martin O. Culjat, Ph.D.
Kayvan Niazi, Ph.D.
Shahrooz Rabizadeh, Ph.D.
Rahul Singh, Ph.D.

Affiliated Faculty

Professors
Marvin Bergsneider, M.D., in Residence (Neurosurgery)
Francisco Bezanilla, Ph.D. (Physiology)
Douglas L. Black, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)
Yong Chen, Ph.D. (Mechanical and Aerospace Engineering)
Samson A. Chow, Ph.D. (Medical and Molecular Pharmacology)
Joseph L. Demer, M.D., Ph.D. (Neurology, Ophthalmology)
Joseph J. DiStefano III, Ph.D. (Computer Science, Medicine)
Bruce S. Dunn, Ph.D. (Materials Science and Engineering)
V. Reggie Edgerton, Ph.D. (Integrative Biology and Physiology)
Alan Garfinkel, Ph.D. (Cardiology, Integrative Biology and Physiology)
Robert P. Gunsalus, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Vijay Gupta, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koehler, M.D. (Medicine)
Jody E. Kreek, Ph.D., in Residence (Surgery)
Eliot M. Landaw, M.D., Ph.D. (Biomathematics)
James C. Liao, Ph.D. (Chemical and Biomolecular Engineering)
Karen M. Lyons, Ph.D. (Cellular and Molecular Medicine, Orthopaedic Surgery)
Thomas G. Mason, Ph.D. (Chemistry and Biochemistry, Physics and Astronomy)
Heather D. Maynard, Ph.D. (Chemistry and Biochemistry)
Harry Mckellop, Ph.D., in Residence (Orthopaedic Surgery)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Moret, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D., in Residence (Medicine)
Peter M. Narr, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
Laurent Pilon, Ph.D. (Mechanical and Aerospace Engineering)
Zhihui Qu, Ph.D., in Residence (Cardiology, Medicine)
Dario L. Ringach, Ph.D. (Neurobiology, Psychology)
Desmond Smith, Ph.D. (Molecular and Medical Pharmacology)
Michael V. Sofroniew, M.D., Ph.D. (Neurobiology)
Igor Spigelman, Ph.D. (Dentistry)
Ren Sun, Ph.D. (Molecular and Medical Pharmacology)
Yi Tang, Ph.D. (Chemical and Biomolecular Engineering)
Ricky Taira, Ph.D., in Residence (Radiological Sciences)
Michael A. Teitell, M.D., Ph.D. (Pathology and Laboratory Medicine, Pediatrics)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
Paul M. Thompson, Ph.D., in Residence (Neurology)
James G. Tidball, Ph.D. (Integrative Biology and Physiology)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Arthur Toga, Ph.D. (Neurology)
Jack Van Horn, Ph.D. (Neurology)
Jeffrey Wang, M.D. (Orthopaedic Surgery)
David Wang, Ph.D. (Dentistry)
Lily Wu, Ph.D., M.D. (Molecular and Medical Pharmacology, Urology)
Z. Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics)

Professor Emeritus
Tony F. Chan, Ph.D. (Mathematics)

Associate Professors
Alex Bui, Ph.D. (Radiological Sciences)
Katrina M. Dipple, M.D., Ph.D. (Human Genetics, Pediatrics)
Jeff D. Eldredge, Ph.D. (Mechanical and Aerospace Engineering)
Xiao Hu, Ph.D., in Residence (Neurosurgery, Surgery)
Y. Suntaek Ju, Ph.D. (Mechanical and Aerospace Engineering)
William S. Klug, Ph.D. (Mechanical and Aerospace Engineering)
Daniel S. Levi, Ph.D. (Pediatrics)
Dejan Markovic, Ph.D. (Electrical Engineering)
Matteo Pellegrini, Ph.D. (Molecular, Cell, and Developmental Biology)
Tatiana Segura, Ph.D. (Chemical and Biomolecular Engineering)
Hsian-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
Danny J.J. Wang, Ph.D., in Residence (Neurology)

Assistant Professors
James W. Bisley, Ph.D. (Neurobiology)
Louis S. Bouchard, Ph.D. (Chemistry and Biochemistry)
Christopher Giza, Ph.D., in Residence (Neurosurgery, Surgery)
Thomas G. Graebner, Ph.D. (Molecular and Medical Pharmacology)
Min Lee, Ph.D. (Dentistry)
Nader Pouratian, Ph.D. (Neurosurgery)
Amy C. Rowat, Ph.D. (Integrative Biology and Physiology)
Dan Ruan, Ph.D. (Radiation Oncology)
Ladan Shams, Ph.D. (Psychology)
Zhouwen Tu, Ph.D., in Residence (Neurology)
Michael R. van Dam, Ph.D. (Molecular and Medical Pharmacology)
Xinshu Grace Xiao, Ph.D. (Integrative Biology and Physiology)

Scope and Objectives
Faculty members in the Department of Bioengineering believe that the interface between biology and engineering is an exciting area for discovery and technology development in the twenty-first century. They have developed an innovative curriculum and created state-of-the-art facilities for cutting-edge research.

The bioengineering program is a structured offering 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. Combined with 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 bioengineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. 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 program educational 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.

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, 4AL, 4BL.

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, 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), Materials Science and Engineering 104, 110, C111, 120, 130, 132, 140, 143A, 150, 151, 160, 161. 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), 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 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study
For information on graduate admission, see Graduate Programs, page 22. The following introductory information is based on the 2013-14 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.
Bioengineering M.S.

Course Requirements
A minimum of 13 courses (44 units) is required, at least 10 of which must be from the 200 series, including three Bioengineering 299 courses and one 495 course. For the thesis plan, at least seven of the 13 must be formal courses and two must be 598 courses involving work on the thesis. For the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirements except for the subfield of medical imaging informatics where 2 units of course 597A are required. Lower division courses may not be applied toward graduate degrees. To remain in good academic standing, M.S. students must maintain an overall grade-point average of 3.0 and a grade-point average of 3.0 in graduate courses. By the end of the first term in residence, students design a course program in consultation with and approved by their faculty advisor.

Comprehensive Examination Plan
The comprehensive examination plan is available in all fields, and requirements vary for each field. Specific details are available from the graduate advisor. Students who fail the examination may repeat it once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are subject to recommendation for termination.

Thesis Plan
Every master’s degree thesis plan requires the completion of an approved thesis that demonstrates student ability to perform original independent research. New students who select this plan are expected to submit the name of the thesis adviser to the graduate adviser by the end of their first term in residence. The thesis adviser serves as chair of the thesis committee.

A research thesis (8 units of Bioengineering 598) is to be written on a bioengineering topic approved by the thesis adviser. The thesis committee consists of the thesis adviser and two other qualified faculty members who are selected from a current list of designated members for the graduate program.

Bioengineering Ph.D.

Course Requirements
To complete the Ph.D. degree, all students must fulfill minimum University requirements. Students must pass the Ph.D. preliminary examination, University Oral Qualifying Examination, and final oral examination, and complete the courses in Group I, Group II, and Group III under Fields of Study below. Also see Course Requirements under Bioengineering M.S. Students must maintain a grade-point average of 3.25 or better in all courses.

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 precandidacy examination requirements. What follows are the requirements for this doctoral program.

The Ph.D. preliminary examination tests a core body of knowledge, and requirements vary for each field. Specific details are available from the graduate advisor. Students who fail the examination may repeat it once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are subject to a recommendation for termination.

Within three terms after passing the Ph.D. preliminary examination, students are strongly encouraged 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 student preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

A doctoral committee consists of a minimum of four qualified UCLA faculty members. Three members, including the chair, are selected from a current list of designated inside members for the graduate program. The outside member must be a qualified UCLA faculty member who does not appear on this list.

A final oral examination (defense of the dissertation) is required of all students.

Fields of Study

Biomedical Instrumentation
The biomedical instrumentation (BMI) field is designed to train bioengineers interested in the applications and development of instrumentation used in medicine and biotechnology. Examples include the use of lasers in surgery and diagnostics, new microelectrical machines for surgery, sensors for detecting and monitoring of disease, microfluidic systems for cell-based diagnostics, new tool development for basic and applied life sciences research, and controlled drug delivery devices. The principles underlying each instrument and specific clinical or biological needs are emphasized. Graduates are targeted principally for employment in academia, government research laboratories, and the biotechnology, medical devices, and biomedical industries.

Course Requirements
Group I: Core Courses on General Concepts. At least three courses selected from Bioengineering C201, C204, C205, C206. Group II: Field Specific Courses. At least three courses selected from Bioengineering CM202 (or CM203 or Molecular, Cell, and Developmental Biology 165A), CM250A, Electrical Engineering 100. Group III: Field Elective Courses. The remainder of the courses must be selected from one of the following three areas:


Other electives are approved on a case-by-case basis.
Imaging, Informatics, and Systems Engineering

The imaging, informatics, and systems engineering (IIS) field consists of the following four subfields:

Biomedical Signal and Image Processing Subfield

The biomedical signal and image processing (BSIP) program prepares students for careers in the acquisition and analysis of biomedical signals and enables students to apply quantitative methods to extract meaningful information for both clinical and research applications. The program is premised on the fact that a core set of mathematical and statistical methods are held in common across signal acquisition and imaging modalities and across data analyses regardless of their dimensionality. These include signal transduction, characterization and analysis of noise, transform analysis, feature extraction from time series or images, quantitative image processing, and imaging physics. Students have the opportunity to focus their work over a broad range of modalities, including electrophysiology, optical imaging methods, MRI, CT, PET, and other tomographic devices, and/or on the extraction of image features such as organ morphology or neurofunctional signals, and detailed anatomic/functional feature extraction. Career opportunities for BSIP trainees include medical instrumentation, engineering positions in medical imaging, and research in the application of advanced engineering skills to the study of anatomy and function.

Group I: Core Courses on General Concepts. Three courses selected from Bioengineering C201 (or CM286) and either CM202 and CM203, OR Molecular, Cell, and Developmental Biology 144 and Physiological Science 166.

Group II: Subfield Specific Courses. At least three courses selected from Biomedical Physics 205, M219, M248, Electrical Engineering 239AS, 266, Neurobiology M200C, Neuroscience CM272, M287, and one course from Bioengineering 165EW, Biomatics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.


Group IV: Subfield Ethics Course. One course selected from Bioengineering 165EW, Biomatics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Biomedical Signal and Image Processing Subfield

Graduate study in biosystems science and engineering (BSSE) emphasizes the systems aspects of living processes, as well as their component parts. It is intended for science and engineering students interested in understanding biocontrol, regulation, communication, and measurement or visualization of biosystems (of aggregate parts—whole systems), for basic or clinical applications. Dynamic systems engineering, mathematical, statistical, and multiscale computational modeling and optimization methods—applicable at all biosystems levels—form the theoretical underpinnings of the field. They are the paradigms for exploring the integrative and hierarchical dynamical properties of biomedical systems quantitatively—at molecular, cellular, organ, whole organism, or societal levels—and leveraging them in applications. The academic program provides directed interdisciplinary biosystems studies in these areas, as well as quantitative dynamic systems biomodeling methods—integrated with the biology for specialized life sciences domain studies of interest to the students.

Typical research areas include molecular and cellular systems physiology, organ systems physiology, and medical, pharmacological, and pharmacogenomic systems studies, neurosystems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. The program fosters careers in research and teaching in systems biology/physiology, engineering, medicine, and/or the biomedical sciences, or research and development in the biomedical or pharmaceutical industry.

Group I: Core Courses on General Concepts. Two physiology/molecular, cellular, and organ systems biology courses from either Bioengineering CM202 and CM203, OR Physiological Science 166 and Molecular, Cell, and Developmental Biology M140, OR 144 and another approved equivalent course, and two dynamic biosystems modeling, estimation, and optimization courses from Bioengineering CM286, and either Biomatics 220 or 296B.


Group III: Subfield Ethics Course. One course selected from Bioengineering 165EW, Biomatics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Medical Imaging Informatics Subfield

Medical imaging informatics (MI) is the rapidly evolving field that combines biomedical informatics and imaging, developing and adapting core methods in informatics to improve the usage and application of imaging in healthcare. Graduate study encompasses principles from across engineering, computer science, information sciences, and biomedicine. Imaging informatics research concerns itself with the full spectrum of low-level concepts (e.g., image standardization and processing, image feature extraction) to higher-level abstractions (e.g., associating semantic meaning to a region in an image, visualization and fusion of images with other biomedical data) and ultimately, applications and the derivation of new knowledge from imaging. Medical imaging informatics addresses not only the images themselves, but encompasses the associated (clinical) data to understand the context of the imaging study, to document observations, and to correlate and reach new conclusions about a disease and the course of a medical problem.

Research foci include distributed medical information architectures and systems, medical image understanding and applications of image processing, medical natural language processing, knowledge engineering and medical decision-support, and medical data visualization. Coursework is geared toward students with science and engineering backgrounds, introducing them to these areas in addition to providing exposure to fundamental biomedical informatics, imaging, and clinical issues. The area encourages multidisciplinary training with faculty members from multiple departments and emphasizes the practical translational development and evaluation of tools/applications to support clinical research and care.


Group II: Subfield Specific Courses. M.S. or pre-health students must take three courses and Ph.D. students must take six
courses from any of the following concentrations:

- Computer Understanding of Images: Bio-
  medical Physics 210, 214, M219, M230,
  M266, Computer Science M266A, M266B,
  276B, Electrical Engineering 211A

- Computer Understanding of Text and Medi-
  cal Information Retrieval: Computer Science
  263A, 263B, Information Studies 228, 245,
  246, 260, Linguistics 218, 232, Statistics
  M231

- Information Networks and Data Access in
  Medical Environment: Computer Science
  240B, 241A, 244A, 245A, 246

- Probabilistic Modeling and Visualiza-
  tion of Medical Data: Biostatistics M209,
  M232, M234, M235, M236, Computer Science
  241B, 262A, 262B, M262C, Information Studies
  272, 277

Group III: Subfield Ethics Course. One
  course selected from Bioengineering
  165EW, Bi mathematic M261, Microbi-
  ology, Immunology, and Molecular Genetics
  C134, or Neuroscience 207

Neuroengineering Subfield

The neuroengineering (NE) subfield is
designed to enable students with a back-
ground in biological sciences to develop and
execute projects that make use of state-of-
the-art technology, including microelectro-
mechanical systems (MEMS), signal pro-
cessing, and photonics. Students with a
background in engineering develop and exe-
cute projects that address problems that
have a neuroscientific base, including loco-
motion and pattern generation, central con-
trol of movement, and the processing of
sensory information. Trainees develop the
capacity for the multidisciplinary teamwork,
in intellectually and socially diverse settings,
that is necessary for new scientific insights
and dramatic technological progress in the
21st century. Students take a curriculum
designed to encourage cross-fertilization of
neuroscience and engineering. The goal is
for neuroscientists and engineers to speak
each other’s language and move comfort-
ably among the intellectual domains of the
two fields.

Group I: Core Courses on General Con-
cepts. Three courses selected from Bioengi-
neering C201 (or CM286) and either CM202
and CM203, OR Molecular, Cell, and Devel-
opmental Biology 144 and Physiological
Science 166.

Group II: Subfield Specific Courses. Bioengi-
neering M260, M261A, M284, and one
course from 165EW, Bi mathematic M261,
Microbiology, Immunology, and Molecular
Genetics C134, or Neuroscience 207.

Group III: Subfield Elective Courses. Two
courses from one of the following two con-
centrations:

- Electronic Engineering: Chemical Engineer-
ing CM215, CM225, Electrical Engineering
  210A, M214A, 214B, 216B, CM250A,
  M250B, CM250L, M252

- Neuroscience: Bioengineering C206, M263,
  Neuroscience M201, M202, 205

Molecular Cellular Tissue
Therapeutics

The molecular cellular tissue therapeutics
(MCTT) field covers novel therapeutic devel-
opment across all biological length scales
from molecules to cells to tissues. At the
molecular and cellular levels, this research
area encompasses the engineering of bio-
materials, ligands, enzymes, protein-protein
interactions, intracellular trafficking, biological
signal transduction, genetic regulation, cellular
metabolism, drug delivery vehicles, and
and cell-cell interactions, as well as the develop-
ment of chemical/biological tools to achieve

At the tissue level, the field encompasses
two subfields—biomaterials and tissue engi-
neering. The properties of bone, muscles,
and tissues, the replacement of natural
materials with artificial compatible and func-
tional materials such as polymers, composites,
ceramics, and metals, and the complex
interactions between implants and the body
are studied at the tissue level. The research
emphasis is on the fundamental basis for
diagnosis, disease treatment, and redesign of
molecular, cellular, and tissue functions. In
addition to quantitative experiments required
to obtain spatial and temporal information,
quantitative and integrative modeling
approaches at the molecular, cellular,
and tissue levels are also included within this field.

Although some of the research remains
exclusively at one length scale, research that
bridges any two or all three length scales is
also an integral part of this field. Graduates
are targeted principally for employment in
academia, government research laborato-
ries, and the biotechnology, pharmaceutical,
and biomedical industries.

Course Requirements

Group I: Core Courses on General Con-
cepts. At least three courses selected from
Bioengineering C201, C204, C205, C206.

Group II: Field Specific Courses. At least
three courses selected from Bioengineering
100, 110, 120, 176, CM278, C283, C285.

Group III: Field Elective Courses. The remain-
der of the courses must be selected from
Bioengineering 180, M215, M225, CM240,
CM245, CM287, Bi mathematic M201,
M203, M211, 220, M270, M271, Chemistry
and Biochemistry 153A, 153B, M230B,
CM260A, CM260B, CM265, 269A, 269D,
277, C281, Materials Science and Engineer-
ing 110, C111, 200, 201, Mechanical and
Aerospace Engineering 156A, M168, Micro-
biology, Immunology, and Molecular Genet-
ics 185A, Molecular and Medical
Pharmacology M110A, 110B, 203, 211A,
211B, 288, Molecular, Cell, and Develop-
mental Biology 100, M140, 144, 165A,
C222D, 224, M230B, M234, Neuroscience
205, Pathology and Laboratory Medicine
M237, 294.

Other electives are approved on a case-by-
case basis

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 fMRI data analysis, ultra-low field
MRI using SQUID detection, low energy
focused ultrasound for neurostimulation

Ian A. Cook, M.D. (Yale, 1987)

Brain function in normal states and cognitive
disorders, blood brain barrier, effects of antide-
pressants on the brain, methods of treatment
for mood disorders especially depression

Linda L. Demer, M.D., Ph.D. (Johns Hopkins,
1983)

Vascular biology, biomaterialization, vascular cal-
cification, mesenchymal stem cells

Timothy J. Deming, Ph.D. (UC Berkeley, 1993)

Polymer synthesis, polymer processing, supra-
molecular materials, organometallic catalysis,
bimimetic materials, polypeptides

James Dunn, M.D., Ph.D. (Harvard, MIT, 1992)

Tissue engineering, stem cell therapy, regener-
active medicine

Robin L. Garrell, Ph.D. (U. Michigan, 1984)

Bioanalytical and surface chemistry with emphasis on
fundamentals and applications of adhesion and wetting

Warren S. Grundfest, M.D., FACS (Columbia,
1980)

Enzyme laser, minimally invasive surgery, bio-
logical spectroscopy

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)

Molecular mechanics, nanofluidics, and bio-
nano research

Dean Ho, Ph.D. (UCLA, 2005)

Nanodiamond hydrogel-based drug delivery system, nanodiamond-embedded patch device as a localized drug-delivery implantable micro-
film, nanocloak film technology for noninvasive
localized drug delivery

Balbram Jalali, Ph.D. (Columbia, 1989)

RF photonics, fiber-optic integrated circuits, integrated optics, microwave photonics

Chang-Jin Kim, Ph.D. (UC Berkeley, 1991)

Microelectromechanical systems: micro/nano
fabrication technologies, structures, actuators,
devices, and systems; microfluidics involving
surface tension (especially droplets)

Wentai Liu, Ph.D. (Michigan, Ann Arbor, 1983)

Neural engineering

North Carolina-Chapel Hill, 1998)

Molecular signaling (NF-KB and Wnt) tumor-
invasive growth and metastasis, adult mesen-
chymal stem cells, dental stem cells and regen-
erative medicine, inflammation and innate immunity.

Gerald C.L. Wong, Ph.D. (UC Berkeley, 1994)
Antimicrobials and antibiotic-resistant pathogens, bacterial communities, cystic fibrosis, apoptosis proteins and cancer therapeutics, disinfec tion and water purification, self-assembly in biology of biotechnology, physical chemistry of solvation, soft condensed matter physics, biophysics.

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

Yang Yang, Ph.D. (Massachusetts-Lowell, 1992)
Conjugated polymers and applications in optoelectronic devices such as light-emitting diodes, photodiodes, and field-effect transistors.

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: biotechnology, instrumentation, and material sciences. Bioinstrumentation, and biological processing, biomechanics, biomaterials, tissue engineering, biotechnology, biological imaging, biomedical optics and lasers, neuroengineering, 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 interest, guided 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). Individually arranged; 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 network analysis. Letter grading.

Mr. Kamei (W)


Mr. Kamei (F)

C102. Basic Human Biology for Bioengineers I. (4) (Formerly numbered Engineering C102.) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological 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. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course C202. Letter grading.

Mr. Grundfest (F)

C103. Basic Human Biology for Bioengineers II. (4) (Formerly numbered Biomedical Engineering C103.) Lecture, four hours; discussion, two hours; Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, musculoskeletal, endocrine, immune, urinary, reproductive). System-specific modeling/simulations (immune regulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (diagnosis, artificial skin, pathogen detectors, ultrasound, blood-control drug delivery). Concurrently scheduled with course CM203. Letter grading.

Mr. Grundfest (W)

C104. Physical Chemistry of Biomacromolecules. (4) (Formerly numbered M104.) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced 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 fundamentals of polymer physical chemistry. Investigation of polymer structure and conformation, bulk and solution thermodynamics and fiber phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, solution of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C204. Letter grading.

Ms. Kasko (F)

C105. Engineering of Bioconjugates. (4) (Formerly numbered M105.) Lecture, three hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry plays a role in medicine, biology, and many paths of discovery at UCLA. P/NP grading.

Mr. Deming (W)

C106. Topics in Biophysics, Channels, and Membranes. (4) (Formerly numbered M106.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4, 23L, Mathematics 33B, Physics 1C, 4AL, 4BL. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrotaxis in dielectric media, building on complexity to ultimately address action potential propagation in nerves. Topics include Nerst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan exclusion, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course CM205. Letter grading.

Mr. Schmidt (Not offered 2013-14)

C107. Polymer Chemistry for Bioengineers. (4) (Formerly numbered M107.) Lecture, four hours; discussion, one hour; outside study, seven hours. Required requisites: course C104 or C105. 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 stereoregularity in polymerizations. Presentation of applications of use of different polymerization techniques. Concepts of 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 C207. Letter grading.

Mr. Deming (W)

110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 109, Mathematics 33B. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body,
extracorporeal devices, tissue engineering systems, and bioartificial organs. Introduction to pharmacoki-
netics and toxicology. Prerequisites: Mr. Kamei (Sp) 
120. Biomedical Transducers, (4) Lecture, four 
hours; discussion, one hour; outside study, seven 
hours. Enforced requisites: Chemistry 30A, Electrical 
Engineering 1 or Physics 1C, Electrical Engineering 
100, Mechanics of Tissues 102, Electronics 13, 23L. 
Selected topics in molecular biology that form foun-
dation of biotechnology and biomedical industry 
today. Topics include recombinant DNA technology, 
molecular biology, gene expression, directed mutagenesis and protein engineer-
ing, DNA-based diagnostics and DNA microarrays, 
and bioinformatics. Emphasis on silicon- 
nanopores. Physics of pore conductance. Applica-
tions in the study of water transport, protein trans-
ference, and DNA sequencing. Overview of current 
literature and fundamental principles. Letter 
grading. Mr. Di Carlo (Sp) 
155EW. Bioengineering Ethics. (4) Lecture, four 
hours; discussion, three hours; outside study, five 
hours. Enforced requisites: chemical engineering 
139A. Biomolecular Materials Science I. (4) 
Novel materials, biocompatibility, biostability. Safety 
of electronic interfaces. Actuator design and interfac-
ing control. Letter grading. 
156. Introduction to Biomechanics. (4) Formerly 
named Mechanical Engineering 115. Lecture, four 
hours; discussion, one hour; outside study, seven 
hours. Requisites: courses 100, 120, Life Sciences 2, 
23L, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluc-
tuating ionic conductance through artificial or protein 
nanopores. Physics of pore conductance. Applica-
tions to single molecule detection and DNA sequenc-
ing. Requisites: course CM102, Chemistry 20A, 20B, 20L, 
Life Sciences 1 or 2. Overview of central topics of tissue 
engineering, proteases and their inhibitors, 
clinical limitations, and regulatory challenges 
in design and development of tissue-engineering de-
vices. Concurrently scheduled with course C231. 
Introduction to mechanical functions of human body; 
teaching in medicine, ethics addresses ethical problems about producing 
when are weapons too dangerous to design? At 
what point does benefit of committing to building de-
vice outweigh need to wait for more scientific confir-
mation of their effectiveness? Bioengineers must be 
aware of consequences of applying such devices to 
all living systems. Emphasis on research and writing 
when emerging technologies and microelectromechanical systems (MEMS) address ethical 
issues. Bioethics is well-established disci-
pline that addresses ethical problems about life, such as when 
do fertilized eggs become people? Should 
eating in life ever be allowed? What should be 
emphasized. Review of current literature and technological ap-
lications. History and instrumentation of resistive 
pulse sensing, theory and instrumentation of electric-
ality. Novel materials, bio- 


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. Bio-compatibility at systemic, tissue, cellular, and molecular levels. Biomechanical compatibility, stress/strain constituencies, scaffolds, adhesion, and clotting, biocompatibility, and immune responses. Letter grading. Mr. Wu (Sp) 177A. Bioengineering Capstone Design I. (4) Formerly numbered 182A.) 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. Sources and ordering of materials and supplies relevant to student projects. Exploration of different experimental and computational methods. Scientific presentation of progress. Concurrently scheduled with course C279. Letter grading. Mr. Di Carlo, Mr. Wong (F) 177B. Bioengineering Capstone Design II. (4) Formerly numbered 182B.) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: courses 176A, 177A. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic design, including meetings with scientific/clinical advisers and guest lectures from scientists in industry and academia. 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. Critiques of oral presentations and written reports to explain how to proceed for research results. May be repeated once for credit with topic or instructor change. Letter grading. 181L. System Integration in Biology, Engineering, and Medicine I. Laboratory. (4) Lecture, one hour; laboratory, four hours; clinical visits, three hours; outside study, three hours. Corequisite: course 180. Hands-on experimentation and clinical applications of selected medical therapeutic devices associated with cardiovascular and pulmonary disorders. Letter grading. Mr. Dunn, Mr. Wu (W) 181L. System Integration in Biology, Engineering, and Medicine II. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: 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. Letter grading. Mr. Dunn, Mr. Wu (W) 181L. System Integration in Biology, Engineering, and Medicine II. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapies 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. Drug pharmacodynamics and clinical pharmacokinetics. Application of engineering principles (diffusion, transport, and kinetics) to problems in drug formulation and delivery. Concurrently scheduled with course C278. Letter grading. Mr. Dunn, Mr. Wu (W) 184. Introduction to Computational and Systems Biology. (2 to 4) (Formerly numbered Biomedical Engineering CM184.) Lecture, one hour; discussion, four hours; laboratory, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. Hands-on experimentation and clinical applications of selected medical therapeutic devices associated with systems at multiple levels of organization. Control system, multicellular, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular, (biomedical pathways/networks), organ, and organismal levels. Both theory- and data-driven modeling, with focus on translating biomodeling to disease and therapeutic and engineering models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PO laboratory assignments. Concurrently scheduled with course CM86. Letter grading. Mr. Di Stefano (F) 187. Research Communication in Computational and Systems Biology. (2 to 4) (Formerly numbered Biomedical Engineering CM187.) (Same as Computational and Systems Biology CM186 and Computer Science CM187.) Lecture, four hours; 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. Critiques of oral presentations and written reports to explain how to proceed for research results. May be repeated once for credit with topic or instructor change. Letter grading. 190. Research Group Seminars: Bioengineering. (4) Lecture, three hours; discussion, one hour; laboratory, four hours. Student-directed research for 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. 199. Directed Research in Bioengineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervisor: individual faculty, with student under guidance of faculty mentor. Culumminating paper or project required. May be repeated for credit with school approval. Individual contract required; enrollment possible only with written permission of Office of Academic and Student Affairs. 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 33B, Physics 1B. Application of engineering principles for designing and understanding delivery of therapeutics. Discussion of physics and mathematics required for understanding coloidal stability. Analysis of concepts related to both modeling and mathematics required for understanding colloidal stability. Analysis of concepts related to both modeling and understanding of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approaches. Application of concepts and techniques associated with course C101. Letter grading. Mr. Kamei (F) 202. Basic Human Biology for Bioengineers I. (4) Formerly numbered Biomedical Engineering CM202.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of human biological activities and organization of human body in system (organ/tissue) to system, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demon-
stration of biomedical instruments, as well as visits to healthcare environments. With a focus on the design and implementation of basic protocols for healthcare environments, with emphasis on use of Dicom. Introduction to basic methods and tools used within the field. Integration of basic concepts for medical applications, with focus on clinical issues demonstrated through examples. Concurrently scheduled with courses 223A, 223B, and 223C to reinforce concepts presented with practical experience. Projects focus on clinical and imaging informatics, knowledge representation, and visualization. Mr. Meng (FW,Sp)

224A. Physics and Informatics of Medical Imaging. (4) (Formerly numbered Biomedical Engineering 224A, Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B, and 34A or 34B. Designed for graduate students. Introduction to principles of medical imaging and informatics for nonphysi- cists. Overview of core imaging modalities: X-ray, computed tomography, magnetic resonance (MR). Topics include signal generation, localization, and quantization. Image representation and analysis techniques such as Markov random fields, energy representations, and clinical imaging workstation design. Provides basic understanding of issues related to digital medical image acquisition and analysis. Current research efforts focus on clinical applications and new types of information made available through these modalities. Letter grading.

224B. Advances in Imaging Informatics. (4) (Formerly numbered Biomedical Engineering 224B, Lecture, four hours; outside study, eight hours. Requisite: course 224A. Overview of information retrieval techniques in biomedical imaging and informatics-based applications of imaging, with focus on various advances in field. Introduction to core concepts in information retrieval (IR), reviewing seminal papers on evaluating IR systems and their use in specific applications (e.g., teaching files, case-based retrieval, etc.). Medical content-based image retrieval (CBIR) as motivating applica- tion, with examination of core works in this area. Techniques to realize medical CBIR, including image feature extraction and processing, feature representation, classification schemes (via machine learning), image indexing, image querying methods, and visualization of images (e.g., perception, presentation). Discussion of more advanced methods now being pur- sued by researchers. Letter grading.

225. Bioseparations and Bioprocess Engineering. (4) (Formerly numbered Biomedical Engineering 225.) (Same as Chemical Engineering C225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Corequisite: Chemical Engineering 10A. Separation strategies, and economic factors used to design processes for isolating and purifying materials like whole cells, en-
zymes, food additives, or pharmaceuticals that are products of biological reactors. Letter grading.

Mr. Montagutte (W)

M226. Medical Knowledge Representation. (4) (Formerly numbered Biomedical Engineering M226.) (Same as Information Studies M233.) Seminar, four hours; outside study, eight hours. Designed for graduate students. Overview of representation and its application in healthcare processes. Topics include data structures used for representing knowledge (conceptual graphs, frame-based representations, case-based data models for reasoning over spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (data mining, statistical classifiers, and hierarchical clustering). Also basic information retrieval. Review of work in constructing ontologies, with focus on problems in implementation and definition. Common medical ontologies, coding schemes, and standardized indices/terminologies (SNOMED, UMLS). Letter grading.

Mr. Taira (Sp)

M227. Medical Information Infrastructures and Internet Technologies. (4) (Formerly numbered Biomedical Engineering M227.) (Same as Information Studies M234.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to networking, communications, and information infrastructures in medical environment. Exposure to standards related to networking (e.g., several lower-level (TCP/IP, services), medium-level (network topologies), and high-level (distributed computing, Web-based services) implementations. Commonly used communication protocols (HIL, DICT) and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless health systems, peer-to-peer topologies, grid/cloud computing. Introduction to security and encryption in networked environments. Letter grading.

Mr. Bui (F)

M229. Medical Decision Making. (4) (Formerly numbered Biomedical Engineering M229.) (Same as Information Studies M255.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and applications of decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing, and estimation. Focus on technical advances in medical decision support systems and how they interact with review of decision process and current research. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading.

Mr. Karakalio (W)

C231. Nanopore Sensing. (4) (Formerly numbered Biomedical Engineering C231.) Lecture, four hours; discussion, one hour; outside study, seven hours. 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 nanopores. Physics of pore conductance. Applications to single molecule detection (DNA sequencing). Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrical measurements in electronics. Comparison between 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 C131. Letter grading.

Mr. Schmidt (F)

C233A. Advancing Bioengineering Innovations I: Unmet Needs. (4) Lecture, three hours; discussion, three hours. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Focus on understanding how to identify unmet clinical needs, properly filtering through these needs using various acceptance criteria, and selecting promising needs for which potential medtech solutions are explored. Students work in groups to expedite traditional research and development processes to invent and implement new medtech devices that increase quality of clinical care and result in improved patient outcomes in hospital system. Introduction to intellectual property basics and various medtech business models. Letter grading.

Mr. Wu (W)

C233B. Advancing Bioengineering Innovations II: Developing and Implementing Medtech Solutions. (4) Lecture, three hours; outside study, nine hours. Explores regulatory and business aspects of medtech development. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin, neural, and other organs. Clinical and industrial perspectives of tissue engineering products. 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)

C233D. Introduction to Biological Imaging. (4) (Formerly numbered Biomedical Engineering M248.) (Same as Mechanical and Aerospace Engineering CM250B.) Lecture, four hours; discussion, two hours; outside study, seven hours. Integration of basics of imaging technologies and microelectromechanical systems (MEMS). Methods of micromanipulation and how these methods can be used to produce variety of MEMS, including microstructures, microsystems, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM150. Letter grading.

Mr. Chiou (W)

C235. Microelectromechanical Systems (MEMS) Fabrication. (4) (Formerly numbered Biomedical Engineering M250B.) (Same as Electrical Engineering CM250L.) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course CM150 or CM250A. Advanced discussion of micromanipulation processes used to construct MEMS. Coverage of many ultrasonic, 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)

C235L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Formerly numbered Biomedical Engineering CM250L.) (Same as Electrical Engineering CM250L and Mechanical and Aerospace Engineering CM280L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: courses CM250A, CM250B, CM250C, CM250D, 4AL, 4BL, 4BL. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromanipulation and how these methods can be used to produce variety of MEMS, including microstructures, microsystems, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM150L. Letter grading.

Mr. Chiou (F)

C235M. Microelectromechanical Systems (MEMS) Design. (4) (Formerly numbered Biomedical Engineering M252.) (Same as Electrical Engineering M252 and Mechanical and Aerospace Engineering M282.) Lecture, four hours; outside study, eight hours. Concurrently scheduled with course CM145. Letter grading.

Mr. Liao (F)
study, eight hours. Introduction to MEMS design. De- sign methods, design rules, sensing and actuation mechanism, microfabrication, and micromotors. De- signing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading.

Mr. Wu (Sp)


Mr. Di Carlo (Sp)


M260. Neuroengineering. (4) Formerly numbered Biomedical Engineering M260.) (Same as Electrical Engineering 260.) Lecture, four hours; labora- tory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. Introduction to biologically inspired circuits and devices for biocompatible systems for bioelectricity, bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity, electro- physiology (action potentials, local field potentials, EEG, ECoG), intracellular and extracellular recording, microelectrode techniques, neural signal processing (neural signal frequency bands, filtering, spike detect- ion, spike sorting, stimulation artifact removal), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading.

Mr. Lu (Sp)


M263. Neuroanatomy: Structure and Function of Nervous System. (4) Formerly numbered Biomed- ical Engineering M263.) (Same as Neuroscience M203.) Lecture, three hours; discussion/laboratory, three hours. Course for students in the inter- disciplinary program. Structure and function of the nervous system at cellular histological and regional sys- tems levels, with emphasis on contemporary experi- mental approaches to morphological study of nervous system in discussions of circuits and neural chemistry of major brain regions. Con- sideration of representative vertebrate and inverte- brate nervous systems. Letter grading.

C270. Energy-Tissue Interactions. (4) Formerly numbered Biomedical Engineering C270L. Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Introduction to therapeutic and diagnos- tic use of energy delivery devices in medical and den- tal applications, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C170L. Letter grading. Mr. Grundfest (F)

C270L. Introduction to Techniques in Studying La- ser-Tissue Interaction. (2) Formerly numbered Bio- medical Engineering C270LL. Lecture, four hours; outside study, two hours. Corequisite: course C270. Introduction to simulation and experimental tech- niques used in studying laser-tissue interactions. Topics include computer simulations of light propaga- tion in tissue, measuring absorption spectra of tis- sue/tissue phantoms, making tissue phantoms, de- termination of optical properties of different tissues, techniques of temperature distribution measure- ments. Concurrently scheduled with course C170LL. Letter grading.


C272. Design of Minimally Invasive Surgical Tools. (4) Formerly numbered Biomedical Engineering C272L. Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, 23L, Mathematics 32A. Intro- duction to design principles and engineering con- cepts in design of devices for tools for minimally invasive surgery. Coverage of FDA regula- tory policy and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, bi- opsy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instru- mentation, and integration of devices with therapy. Examination of complex process of tool design, fabri- cation, testing, and validation. Preparation of draw- ings and consideration of development of new and novel devices. Concurrently scheduled with course C171LL. Letter grading. Mr. Grundfest (W)

CM276. Introduction to Biomaterials. (4) Formerly numbered Biomedical Engineering CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships be- tween material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM178L. Letter grading.

Mr. Wu (W)

CM279. Biomaterials-Tissue Interactions. (4) Formerly numbered Biomedical Engineering CM281.) Lecture, three hours; discussion, two hours. Requir- e: course CM278. In-depth exploration of host cel- lular response to biomaterials: vascular response, interface, and closure, biocompatibility, and mor- phology, inflammation, interfacial, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C179L. Letter grading.

Mr. Wu (Sp)

282. Biomaterial Interfaces. (4) Formerly numbered Biomedical Engineering CM282.) Lecture, four hours; laboratory, eight hours. Requisite: course CM178 or CM278. Function, utility, and biocompatibility of bio- materials depend critically on their surface and inter- facial properties. Discussion of morphology and composition of biomaterials and nanoscales, meso- scales, and macroscales, techniques for characteriz- ing structure and properties of biomaterial interfaces, and methods for designing and fabricating biomateri- als with prescribed structure and properties in vitro and in vivo. Letter grading. Ms. Maynard (W)

C283. Targeted Drug Delivery and Controlled Drug Release. (4) Formerly numbered Biomedical Engi- neering C283.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemis- try 20A, 20B, 20L. New therapeutics require com- prehensive understanding of modern biology, physi- ology, biomaterials, and engineering. Targeted deliv- ery of genes and drugs and their controlled release are important in treatment of challenging diseases and cancer to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical phar- macokinetics. Application of engineering principles (diffusion, transport, kinetics) to problems in drug for- mulation and delivery by design of rational drug design and development of novel drug delivery systems that can provide spatial and temporal control of drug re- lease. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and re- lease. Concurrently scheduled with course C183. Letter grading.

Mr. Wu (Sp)


Mr. Wu (Sp)

CM286. Computational Systems Biology: Model- ing and Simulation of Biological Systems. (5) For- merly numbered Biomedical Engineering CM286.) (Same as Computer Science CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisites: Electrical Engineering 102, Dy- namics of biological systems: modeling and simulation methods for studying biological/biomedical proc- esses and systems at multiple levels of organization. Control system, multiparticle, compartmental, predator-prey, pharmacokinetic (PK), pharmacodynamics (PD), and other structural modeling methods applied to life sci- ences problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theoretic and data-driven models with focus on translating biomodeling goals and data into mathe- matics models and implementing them for simulation and analysis. Basics of numerical simulation algo- rithms, with modeling software packages and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading. Mr. DiStefano (F)

C287. Research Communication in Computa- tional and Systems Biology. (2 to 4) Formerly num- bered Computer Science CM287.) Lecture, four hours; outside study, eight hours. Corequisite: course CM286. Closely directed, interactive, and real research expe- rience in quantitative research, analysis, and computer- based research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and written progress reports to explain how to proceed with search for research results. Ma-
or emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading. Mr. DiStefano (Sp)

295A-295Z. Seminars: Research Topics in Bioengineering. (1 to 4) (Formerly numbered Biomedical Engineering 295A-295Z.) Seminar, one to four hours. Limited to bioengineering graduate students. Advance study and analysis of current topics in bioengineering. Discussion of current research and literature in research specialty of faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit. S/U grading.

295A. Biomedical Research.

295B. Biomaterials and Tissue Engineering Research.

295C. Minimally Invasive and Laser Research.

295D. Hybrid Device Research.

295E. Molecular Cell Biomedicine Research.

295F. Biopolymer Materials and Chemistry.

M296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Formerly numbered Biomedical Engineering M296A.) (Same as Computer Science M296A and Medicine M2970C.) Lecture, four hours; outside study, eight hours. Requisite: Theory of AP 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling for physiologic, biochemical, pharmacological, chemical, and related systems. Control system, multiparametric, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other related data environments. Problem solving in PC laboratory. Letter grading. Mr. DiStefano (F)

M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Formerly numbered Biomedical Engineering M296B.) (Same as Biomathematics M270, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biomathematics 220. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W)

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Formerly numbered Biomedical Engineering M296C.) (Same as Computer Science M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296B. Research techniques and experience on special topics involving models, modeling methods, and model/computing in biological and medical sciences. Review and critique of literature. Research problem solving and formulation. Approaches to solutions. Individual M.S.- and Ph.D.-level project training. Letter grading. Mr. DiStefano (Sp)

M296D. Introduction to Computational Cardiology. (4) (Formerly numbered Biomedical Engineering M296D.) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiologic process, ionic models of action potential (AP), Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading. Mr. Kogan (FSp)

298. Special Studies in Bioengineering. (4) (Formerly numbered Biomedical Engineering 298.) Lecture, four hours; outside study, eight hours. Study of selected topics in bioengineering taught by resident and visiting faculty members. May be repeated for credit. Letter grading.

299. Seminar: Bioengineering Topics. (2) (Formerly numbered Biomedical Engineering 299.) Seminar, two hours; outside study, four hours. Designated for graduate bioengineering students. Seminar by leading academic and industrial bioengineers from UCLA, other universities, and bioengineers, such as Baxter, Amgen, Medtronics, and Guidant, on development and application of recent technological advances in discipline. Exploration of cutting-edge developments and challenges in wound healing models, stem cell biology, angiogenesis, signal transduction, gene therapy, cDNA microarray technology, bioartificial cultivation, nano- and micro-hybrid devices, scaffold engineering, and biostructural. S/U grading. Mr. Wu (F,WSp)

375. Teaching Apprentice Practicum. (4) (Formerly numbered Biomedical Engineering 375.) 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) (Formerly numbered Biomedical Engineering 495.) Seminar, two hours; outside study, four hours. Limited to graduate bioengineering students. Required of all departmental teaching assistants. May be taken concurrently while holding TA appointment. Seminar for communicating bioengineering and biomedical 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) (Formerly numbered Biomedical Engineering 596.) Tutorial, to be arranged. Limited to graduate bioengineering students. Petition forms to request enrollment. May be repeated for credit. S/U grading.

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) (Formerly numbered Biomedical Engineering 597A.) Tutorial, to be arranged. Limited to graduate bioengineering students. Reading and preparation for M.S. comprehensive examination. S/U grading.

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) (Formerly numbered Biomedical Engineering 597B.) Tutorial, to be arranged. Limited to graduate bioengineering students. Reading and preparation for Ph.D. preliminary examinations. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) (Formerly numbered Biomedical Engineering 597C.) Tutorial, to be arranged. Limited to graduate bioengineering 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) (Formerly numbered Biomedical Engineering 598.) Tutorial, to be arranged. Limited to graduate bioengineering 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) (Formerly numbered Biomedical Engineering 599.) Tutorial, to be arranged. Limited to graduate bioengineering students. Usualy taken after students have been advanced to candidacy. S/U grading.
access systems engineering, membrane science, semiconductor processing, chemical 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, biomolecular engineering, environmental engineering, and semiconductor manufacturing engineering options provide students with 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, CM127, 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 18 or http://www.registrar.ucla.edu/ger/.

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 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 18 or http://www.registrar.ucla.edu/ger/.
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 18 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. For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study
 For information on graduate admission, see Graduate Programs, page 22.
 For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure.

The following introductory information is based on the 2013-14 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 Department of Chemical and Biomolecular Engineering offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Chemical Engineering.

Chemical Engineering M.S.
 Areas of Study
 Consult the department.
 For the semiconductor manufacturing field, the program requires that students have advanced knowledge, assessed in a comprehensive examination, of processing semiconductor devices on the nanoscale.

Course Requirements
 The requirements for an M.S. degree are a thesis, nine courses (36 units), and a 3.0 grade-point average in the graduate courses. Chemical Engineering 200, 210, and 220 are required for all M.S. degree candidates. Two courses must be taken from offerings in the Chemical and Biomolecular Engineering Department, while two Chemical Engineering 598 courses involving work on the thesis may also be selected. The remaining two courses may be taken from those offered by the department or any other field in life sciences, physical sciences, mathematics, or engineering. At least 24 units must be in letter-graded 200-level courses.
 All M.S. students are required to enroll in the seminar, Chemical Engineering 299, during each term in residence.
 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, M152B, 199; Electrical Engineering 100, 101A, 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 104/C/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 221A, 221B, 223, 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 for approval before the end of the first term in residence.

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.

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 evaluation (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) potentiostat/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) phosphomager 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 mathe-
mical 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 spectrometry; a surface analytical facility including X-ray photoelectron spectroscopy. Auger electron spectroscopy, ultraviolet 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 ultrahigh 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 biomedicals, 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
membranes, water desalination, adsorption, Laboratory is equipped for research on The Polymer and Separations Research Laboratory Polymeric and novel ceramic-fluid flow through channels of different 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 viscosimeter, narrow gap cylindrical couette viscometer, cone-and-plate viscometer, intrinsic viscosity viscometer 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 UNDO. 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 nanostructuring, 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

Vijay K. Dhir, Ph.D. (U. Kentucky, 1972) Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling

Robert F. Hicks, Ph.D. (U.C Berkeley, 1984) Chemical vapor deposition and atmospheric plasma processing


Yunfeng Lu, Ph.D. (U. New Mexico, 1998) Semiconductor manufacturing and nanotechnology

Vassiliou I. Manousiouthakis, Ph.D. (Rensselaer, 1986) Process systems engineering: modeling, simulation, design, optimization, and control

Harold G. Morbouquette, Ph.D. (North Carolina State, 1987) Biochemical engineering, biosensors, nanotechnology

Selim M. Senkan, Ph.D. (MIT, 1977) Reaction engineering, combinatorial catalysis, combustion, laser photoionization, real-time detection, quantum chemistry

Yi Tang, Ph.D. (Caltech, 2002) Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibacterial/antifungal products

Professors Emeriti

Louis J. Ignararo, Ph.D. (Minnesota, 1966) Regulation and modulation of NO production

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


Associate Processor


Assistant Professors

Yvonne Y. Chen, Ph.D. (Caltech, 2011) Synthetic biology, gene-circuit engineering, cell-based therapy, T-cell engineering

Gerassimos 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 agricultural economies compared and contrasted with natural flows; presentation of lifecycle methods for evaluating environmental impact of processes and products. P/NP or letter grading. Mr. Manusiotakis (Not offered 2013-14)

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 current technological problems in production of microelectronic devices, design of chemical plants for minimum environmental impact, application of nanotechnology to chemical sensing, and genetic-level design of recombinant microbes for chemical synthesis. Letter grading. Mr. Liao (P)

18. 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. Fundamentals of Chemical and Biomolecular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 102B, 20L; Mathematics 32B (may be taken concurrently), Physics 1A. Introduction to analysis and design of chemical processes. Mass and energy balances. Introduction to programming in MATLAB. Letter grading. Mr. Manousiouthakis (FW)


102A. Thermodynamics I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to thermodynamics of chemical and biological processes. Work, energy, heat, and first law of thermodynamics. Second law, extremum principles, entropy, and free energy. Ideal and real gases, property evaluation. Thermodynamics of flow systems. Applications of first and second laws in biological processes and living organisms. Letter grading.

102B. Thermodynamics II. (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 design and operation of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading.

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 design and operation of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading.

104A. Chemical and Biomolecular Engineering Laboratory I. (4) Formerly numbered 104AL. Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite: course 100. Corequisite: course 101B. Recommended: course 202B. Not open for credit to students with credit for former course 104AL. Investigation of basic transport phenomena in 10 predetermined experiments, collection of data for statistical analysis and individual 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 statistical methods: mean, standard deviation, confidence limits, comparison of two means and of multiple means, single and multiple variable linear regression, and brief introduction to factorial design of experiments. Oral and poster presentations. Technical writing of sections of laboratory manual; writing clearly, concisely, and consistently; importance of word choices and punctuation in multicultural engineering environment and of following required formatting. Letter grading.

104B. Chemical and Biomolecular Engineering Laboratory II. (6) Lecture, four hours; laboratory, eight hours; outside study, four hours; other, two hours. Requisites: courses 101C, 103, 104A. Course consists of four 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 protocol, and process design and error analysis. Letter grading.

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Requisite: course 101C. Corequisite: course 104D. Basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metallization, and statistical design of experiments and error analysis. Presentation of student results in both written and oral form. Letter grading.

104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours; outside study, five hours. Requisite: course 101C. Corequisite: course 104C. Series of experiments that emphasize basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metallization, and statistical design of experiments and error analysis. Hands-on device fabrication and measurement of transistors, diodes, and capacitors. Letter grading.


107. 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 startup behavior of chemical engineering processes. Chemical process control elements. Design and applications of chemical process computer control. Letter grading.

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study. Requisites: courses 103 or (C125), 104A, 106 or (C115). Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering with economic principles to support the purposes of designing chemical processes and evaluating alternatives. Letter grading.

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study. Requisites: courses 103 or (C125), 106 or (C115), 108A. Computer Science 31. Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading.

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Computer Science 101A. Numerical methods for computation of solutions of systems of linear and nonlinear algebraic equations, ordinary differential equations, and partial equations. Chemical and biomolecular engineering examples used throughout to illustrate applications of these methods. Use of MATLAB as platform for programming and to write programs based on numerical methods to solve various problems arising in chemical engineering. Letter grading.

110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102B. Principles and engineering applications of statistical and phenomenological thermodynamics. Determination of partition function in terms of simple molecular models and spectroscopic data; nonideal gases; phase transitions and adsorption; nonequilibrium thermodynamics and coupled transport processes. Letter grading.

111. Cryogenics and Low-Temperature Processess. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryogenic engineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course 221L. Letter grading.

112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 30A. Formation of polymer macromolecular criteria for 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 221L. Letter grading.

113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Requisites: courses 101C, 102B. Integrated approach to air pollution, including concentrations of atmospheric pollutants, air pollution standards, air pollution sources and controls, and relationship of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading.

114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 202A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metal corrosion. 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 finishing, passivity, electrodoposition, batteries and fuel cells, elec-
trosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C214. Letter grading. (Not offered 2013–14)

C115. Biochemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven 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 reactors. May be concurrently scheduled with course CM215. Letter grading. Mr. Tang (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 and biological components are commonalities of metabolic engineering and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Through understanding of biochemistry, protein structure, and biological regulations and are aided by tools in bioinformatics, systems biology, and molecular biology. Fundamentals of metabolic, biochemical, and protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM227. Letter grading. (Not offered 2013–14)

C135. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 107. Introduction to advanced process control. Topics include (1) Loopunov 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 various classes of nonlinear systems, (4) model predictive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course C235. Letter grading. Mr. Christofides (Sp)


CM145. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 3, 23L. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA, applications of molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading. Mr. Chen (F)

180. Special Courses in Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in chemical engineering for undergraduate students taught on experimental or temporary basis, such as taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

Mr. Senkan (Not offered 2013–14)


196. Directed Research in Chemical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/ seniors. Supervised individual research or investigation of selected topic under guidance of faculty mentor. May be repeated once for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.

Mr. Manousiouthakis (W)

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 106. Formation of cryosystems and cryoengineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes necessary for radiation and convection heat transfer behavior, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading.

Mr. Yuan (F)

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. Lu (W)

C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven 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 reactors. May be concurrently scheduled with course C114. Letter grading. (Not offered 2013–14)

CM215. Biochemical Reaction Engineering. (4) (Same as Bioengineering M215.) Lecture, four hours; discussion, one hour; outside study, seven 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 reactors. 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, atomic and molecular structures and composition of crystals and their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelec-
217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, corrosion, and electrokinetics, along with applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading.
Mr. Nobe (Not offered 2013-14)

Mr. Cohen (W)

Mr. Cohen (W)

C220. 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 reagent 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 (W)

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, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationships between structure/morphology of dense and porous membranes and their separation characteristics. Modeling of nano/microporous membranes and membranes of transport (flux and selectivity). Topics provided from various fields/applications, including biotechnology, microelectronic processing, and biomedical devices. Concurrently scheduled with course C121. Letter grading.
Mr. Cohen (Not offered 2013-14)

Mr. Manousiouthakis (Not offered 2013-14)

CM227. Synthetic Biology for Biofuels. (4) Same as Chemistry CM227.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 153A, Life Sciences 3, 23L. Engineering microorganisms for complex phenotypes is a common goal of metabolic and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regulations and are aided by tools in bioinformatics, systems biology, and bioinformatics. Fundamentals of metabolic biology, protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM127. S/U or letter grading. (Not offered 2013-14)

Mr. Serkan (Not offered 2013-14)

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

Mr. Serkan (Not offered 2013-14)

233. Frontiers in Biotechnology. (2) Formerly numbered 233. Lecture, one hour. Requisites: Life Sciences 3, 23L. Integration of science and business in biotechnology. Academic research leading to licensing and founding of companies that turn research breakthroughs into commercial enterprises. Invited lecturers from academia and industry cover emerging areas of biotechnology from combination of science, engineering, and business points of view. S/U or letter grading. (W)

234. Plasma Chemistry and Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate chemistry or engineering students. Application of chemistry, physics, and engineering principles to design and demonstration of ion and ion-beam reactors used in etching, deposition, oxidation, and cleaning of materials. Examination of atomic, molecular, and ionic phenomena involved 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 requisite: course 107. Introduction to advanced process control. Topics include (1) Lyapunov 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 various classes of nonlinear systems, (4) model predictive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of systems with parameter uncertainty. Letter grading.
Ms. Chang, Mr. Hicks

236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, seven hours. Topics include application to chemical source, course 210, C216. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic devices. Topics include reactor design, transport phenomena, gas and surface chemical kinetics, structure and composition of deposited films, and relationships between process conditions and film properties. Letter grading.
Mr. Hicks

CM240. Fundamentals of Aerosol Technology. (4) Lecture, four hours; discussion, eight hours. Requisites: course 101C. Technology of particle/gas systems with applications to gas cleaning, commercial production of fine particles, and catalysis. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C140. Letter grading. (Not offered 2013-14)

CM245. Molecular Biotechnology for Engineers. (4) Same as Biotechnology 245.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 3, 23L. Selected topics in molecular biology that form foundation of biotechnology and biomedical research. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading.
Ms. Chen (F)

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; systematicic flowsheet invention; process synthesis; optimal design and operation of large-scale chemical processing systems. Letter grading.
Mr. Manousiouthakis
polymeric liquids and dispersed systems. Applications in viscometry, polymer processing, bioremediology, oil recovery, and drug delivery. Letter grading.

Mr. Cohen

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

270R. Advanced Research in Semiconductor Manufacturing. (6) Laboratory, nine hours; outside study, nine hours. Limited to 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) system 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.

Mr. Christofides

M280C. Optimal Control. (4) (Same as Electrical Engineering M240C and Mechanical and Aerospace Engineering M270C) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 240B or Mechanical and Aerospace Engineering 270B. Applications of variational methods, Pontryagin maximum principle, Hamilton/Jacobi/Bellman equation (dynamical programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading.

Mr. Cohen


Mr. Cohen

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, semigroup theory, convergence theory in function spaces), (2) nonlinear model reduction (linear and nonlinear Galerkin methods, proper orthogonal decomposition), (3) nonlinear and robust control of nonlinear hyperbolic and parabolic partial differential equations (PDEs), (4) applications to transport-reaction processes. Letter grading.

Mr. Cohen


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 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 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 each) 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.

Mr. Cohen

299. Departmental Seminar. (2) Seminar, two hours. Limited to graduate chemical engineering students. Seminars by leading academic and industrial chem 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 Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel placement by department. May be used as substitute teaching assistant. Not to count toward credit for chemical engineering graduate students. S/U grading.

Mr. Cohen

495A. 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. Requisites: 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. (F,W,Sp)

495B. Teaching with Technology for Teaching Assistants. (2) Seminar, to be arranged. 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. (W)

596. 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.

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Seminar, to be arranged. Limited to graduate chemical engineering students. Supervised investigation of advanced technical problems. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Seminar, to be arranged. Limited to graduate chemical engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

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

599. Research and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate chemical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.
Civil and Environmental Engineering

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Jonathan P. Stewart, Ph.D., Chair
Scott J. Brandenberg, Ph.D., Vice Chair
Steven A. Margulis, Ph.D., Vice Chair

Professors
Jiun-Shyan (J-S) Chen, Ph.D.,
Eric M.V. Hoek, Ph.D.,
Jiann-Wen (Woody) Ju, Ph.D.,
Steven A. Margulis, Ph.D.,
Michael K. Stenstrom, Ph.D.,
Jonathan P. Stewart, Ph.D.,
Keith D. Stoltenbach, Ph.D.,
Ertugrul Tacioglu, Ph.D.,
Mladen Vucetic, Ph.D.,
John W. Wallace, Ph.D.,
William W-G. Yeh, Ph.D. (Richard G. Newman AECOM Endowed Professor of Civil Engineering)

Professors Emeriti
Stanley B. Dong, Ph.D.,
Lewis P. Felton, Ph.D.,
Michael E. Fournier, Ph.D.,
Gary C. Hart, Ph.D.,
Poul V. Lade, Ph.D.,
Chung Yen Liu, Ph.D.,
Richard L. Perrine, Ph.D.,
Moshe F. Rubinstein, Ph.D.,
Lucien A. Schmit, Jr., M.S.,
Lawrence G. Selna, Ph.D.,

Associate Professors
Scott J. Brandenberg, Ph.D.,
Mekonnen Gebremichael, Ph.D.,
Jennifer A. Jay, Ph.D.,
Jian Zhang, Ph.D.,

Assistant Professors
Shaily Mahendra, Ph.D.,
Gaurav Sant, Ph.D. (Edward K. and Linda L. Rice Endowed Professor of Materials Science)

Adjunct Professors
Robert E. Kayen, Ph.D.,
Thomas Sabol, Ph.D.,
Ne-Zheng Sun, Ph.D.,

Adjunct Associate Professors
Terri S. Hogue, Ph.D.,
Donald R. Kendall, Ph.D.,
Issam Najmi, Ph.D.,
Daniel E. Pradel, Ph.D.,

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

The civil engineering undergraduate 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 orients 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, 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 selected tracks and the other from any separate track or from the list of additional elective laboratory options:

Environmental Engineering: Required: One capstone design course from Civil and Envi-
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 (4 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, 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 22.

The following introductory information is based on the 2013-14 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 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, 101A, 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 six 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; Mathemat-
ics 32A, 33A; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.

**Required Graduate Courses.** Civil and Environmental Engineering 254A, 255A, 255B, 266.


**Geotechnical Engineering**

**Required Preparatory Courses.** Civil and Environmental Engineering 108, 120, 121.

**Required Graduate Courses.** Civil and Environmental Engineering 220, 221, 223, 224.

**Major Field Elective Courses.** Minimum of three courses must be selected from Civil and Environmental Engineering 123, 128L, 222, 225, 226, 227, 245.


**Hydrology and Water Resources Engineering**

**Required Preparatory Courses.** Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 151, 153; Mathematics 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 1C, 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.

**Elective Courses.** Undergraduate—no more than two courses from Civil and Environmental Engineering 125, M135C, 137, 143, and either 141 or 142; geotechnical area—Civil and Environmental Engineering 220, 221, 222, 223, 225, 227; general graduate—Civil and Environmental Engineering M230A.

**Structural Mechanics**

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

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

**Elective Courses.** Undergraduate—maximum of two courses from Civil and Environmental Engineering M135C, 137, 137L; graduate—Civil and Environmental Engineering M230A, M230B, M230C, 233, 235C, 238, 246, 247, Mechanical and Aerospace Engineering 269B.

**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 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, 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 hydroclimatolgy, watershed response to disturbance, remote sensing, data assimilation, hydrologic modeling and parameter estimation, multiojective 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, micro mechanics 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 methodologies. 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 testing 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 Century City high-rises and retail buildings, this network, which is maintained by the U.S. Geological Society and State of 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.

**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 hardness, 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.
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. floor with anchor points at 3 ft. on center. Actuators with servohydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced 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, 1989)
- Finite element methods, meshfree methods, large deformation mechanics, inelasticity, contact problems, structural dynamics

Eric M.V. Hoek, Ph.D. (Yale, 2001)
- Physical and chemical environmental processes, colloidal and interfacial phenomena, environmental membrane separations, bioadsorption and bio-fouling

Jeffrey (Woody) Ju, Ph.D. (UC Berkeley, 1996)
- Dampage mechanics, mechanics of composite materials, computational plasticity, micromechanics, concrete modeling and durability, computational mechanics

**Associate Professors**

Scott J. Brandenberg, Ph.D. (UC Davis, 2005)
- Geotechnical engineering, soil-structure interaction, liquefaction, data acquisition and processing, numerical analysis

Mekonnen Gebremichael, Ph.D. (U. Iowa, 2004)
- Remote sensing of hydrology, watershed hydrologic modeling, hydrometeorology, stochastic and machine learning

Jennifer A. Jay, Ph.D. (MIT, 1999)
- Aquatic chemistry, environmental microbiology

**Assistant Professors**

Shailly Mahendra, Ph.D. (UC Berkeley, 2007)
- Environmental microbiology, biodegradation of groundwater contaminants, microbial-nanostructure interactions, 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 cracking, thermodynamics of interfaces, durability prediction and extension, and carbon footprint minimization of construction materials

**Adjunct Professors**

Robert E. Kayen, Ph.D. (UC Berkeley, 1993)
- Geometrics and terrestrial laser-topographic modeling, geotechnical earthquake engineering, engineering geology, applied geophysics

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

**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

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

Mr. Stewart (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 programming, with emphasis on numerical techniques and methodology as applied to civil engineering programs. Letter grading.

Mr. Chen, Mr. Margulis (FW)

**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 on ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading.

Ms. Jay (Sp)
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; acceleration of particles, rigid bodies, and rigid frames. Kinematics and kinetics of rigid bodies in two- and three-dimensional motions.

103. Applied Numerical Computing and Modeling in Civil and Environmental Engineering. (4) Lecture; four hours; discussion; two hours; outside study; six hours. Requisites: course 101, Chemistry 20A, 20B, Materials Science 104, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Enforced corequisite: course 108. Introduction to numerical computing with specific applications in civil and environmental engineering. Topics include error and computer arithmetic, root finding, curve fitting, numerical integration and differentiation, solution of systems of linear and nonlinear equations, numerical solution of ordinary and partial differential equations.


105. Geotechnical Engineering. (4) Lecture; four hours; outside study, eight hours. Techniques for effectively communicating technical material accurately, clearly, and briefly, with emphasis on writing and development of oral presentation skills. How to write clearly and effectively. How to organize and logically present it in readable style. edit work accurately, and apply sound writing principles to technical documents. Topics include organization of information; application of techniques to achieve unity, coherence, and development; use of parallel grammatical structure effectively; avoidance of common writing errors; and development of effective conclusions and recommendations. Letter grading.

Ms. Shane (Not offered 2013-14)


Mr. Brandenberg (F)

109. Introduction to Mechanics of Deformable Solids. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Requisites: Mathematics 33A, Physics 1A. Course content.

110. Introduction to Probability and Statistics for Engineers. (4) Lecture; four hours; discussion, one hour (when scheduled); outside study, seven hours. Requisites: Mathematics 32A, 33A. Recommended: course 15. Introduction to fundamental concepts and applications of probability and statistics in civil engineering, with focus on how these concepts are used in experimental design and sampling, data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distributions, functions of random variables, estimating parameters from observed data, regression, hypothesis testing, and Bayesian concepts. Letter grading.

Ms. Zhang (F/W)

120. Principles of Soil Mechanics. (4) Lecture; four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Soil as foundation for 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 120. Design methods for foundations and earth structures; virtual work; analysis of indeterminate structures; transfer coefficients; random variables; functions of random variables; functional forms; estimation of safety factors; hypothesis testing; and Bayesian concepts. Letter grading.

Mr. Zoltenbach (Sp)

125. Advanced Geotechnical Engineering. (4) Lecture; four hours; computer laboratory; two hours; outside study, six hours. Requisite: course 121. Analysis and design of earth dams, including seepage, piping, and slope stability analyses. Case history studies involving landslides, settlement, and expansive soil problems. Analysis of stressstrain problems. Numerical methods for analysis of these problems. Weighted residual, least squares, and finite difference approximations. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation; multilevel analysis; and multilevel integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing techniques; term projects with computers. Letter grading.

Ms. Chen, Mr. Kligerman (F)

M135C. Introduction to Finite Element Methods. (4) (Same as Mechanical and Aerospace Engineering 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 computational control of crack propagation. Overview of finite element analysis and convergence properties; isoparametric formulation of multilevel analysis; and multilevel integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing techniques; term projects with computers. Letter grading.

Mr. Tacioglu, Mr. Wallace (W)
135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Prerequisite: course 135A, 145A, or by permission. Enrollment limited. Computer-aided optimum design, construction, instrumentation, and test of small-scale model structure. Use of computer-based data acquisition and interpretation systems for comparison of experimental and theoretically predicted behavior. Letter grading. Mr. Wallace (Sp)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibration of test facility and dynamic components. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic simulator. 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. Calibration of test facility and dynamic components. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic simulator. Letter grading. Mr. Wallace (Not offered 2013-14)

140L. Structural Components and Systems Testing Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Enrolled in lab req: course 140. Comparison of experimental results with analytical results and code requirements to assess accuracies and limitations of calculation procedures used in structural design. Tests include quasi-static tests of structural elements (beams, columns) and systems (slab-column, beam-column) and dynamic tests of simple building systems. Quasi-static tests focus on assessment of element or subsystem stiffness, strength, and deformation capacity, whereas dynamic tests focus on assessment of periods, mode shapes, and damping. Development of communication skills through preparation of laboratory reports and oral presentations. Letter grading. Mr. Wallace (FSp)

141. Steel Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Introduction to building codes. Fundamentals of load and resistance factor design of steel elements. Design of tension and compression members. Design of beams and beam columns. Simple precast concrete. Introduction to computer modeling methods and design process. Letter grading. Mr. Wallace (F)


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 reinforced 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 2013-14)

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: anchorage/bonding of cables/wire, flexure analysis by superposition and strength method, draping of cables, deflection and stiffness, indentation structures, limit of prestressing. Letter grading. Mr. Wallace (Sp)

144. Structural Systems Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 141 or 142. Design course for civil engineering students, with focus on design and construction of complete building structural systems. International Building Code (IBC) and ASCE 7 dead, live, wind, and earthquake loads. Design of reinforced concrete and structural steel buildings. Computer modeling, analysis, and performance assessment of buildings. Letter grading. Mr. Wallace (Sp)

147. Design and Construction of Tall Buildings. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 135B, 141. Role of structural engineer, architect, and other design professions in design process. Development of architectural design of tall buildings. Influence of building code, zoning, and finance. Advantages and limitations of different structural systems and structures. Development of structural system design and computer model for architectural design. Letter grading. Mr. Sabol, Mr. Wallace (W)

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

151. Design of Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enrolled requisites: course 150, Mechanical and Aerospace Engineering 103. Recommended: courses 103, 110. Properties of hydraulic, flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydroelectric power. Introduction to 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 processes. Introduction to 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. Enrolled requisites: course 150, Mechanical and Aerospace Engineering 103. Recommended: courses 103, 110. Properties of hydraulic, flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydroelectric power. Introduction to system analysis and design applied to water resources engineering. Letter grading. Mr. Margulis (W)

157A. Hydrologic Modeling. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 150, 151. Introduction to hydrologic modeling. Topics selected from areas of (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 focus on use of industry and/or research standard models with locally relevant applications. Letter grading. Mr. Yeh (Sp)

157B. Design of Water Treatment Plants. (4) Lecture, four hours; discussion, two hours; laboratory, 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 cost estimation. Letter grading. Mr. Stenstrom (W)

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 (Not offered 2013-14)

157L. Hydrologic Analysis. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisite: course 150. Collection, compilation, and interpretation of data for quantification of 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. Letter grading. Mr. Stenstrom (Sp)

157M. Hydrology of Mountain Watersheds. (4) Lecture, one hour; fieldwork, four hours; laboratory, three hours; outside study, four hours; one field trip. Requisite: courses 150 or 157L. Advanced field- and laboratory-based course focusing on study of hydrologic and geochemical processes in snow-dominated and mountainous regions. Students measure and quantify snowpack properties, snowmelt, discharge, evaporation, infiltration, soil properties, and local meteorology, as well as investigate geochemical 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 2013-14)

163. Introduction to Atmospheric Chemistry and Air Pollution. (4) Lecture, four hours; outside study, eight hours. Requisite: course 141. Chemistry 20A, 20B, Mathematics 31A, 31B, Physics 1A, 1B. Description of processes affecting chemical composition of troposphere: air pollutant concentrations/standards, urban and regional chemistry, photochemical reaction/deposition of acid precipitation, fate of anthropogenic/toxic/natural organic and inorganic compounds, selected global chemical cycle(s). Control technologies. Letter grading. Mr. Stolzenbach (Not offered 2013-14)

164. Hazardous Waste Site Investigation and Remediation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150, 153, Mechanical and Aerospace Engineering 103. Study of hazardous waste types and potential sources. Techniques in measuring and modeling subsurface flow

Mr. Brandenberg (W)


Mr. Vucetic (F)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 220, 245. Analysis of earthquake-induced ground motion, including soil liquefaction, cyclic softening of clays, seismic compression, surface fault rupture, and aseismic slope stability. Ground response effects on earthquake ground motions. Soil-structure interaction, including inertial and kinematic interaction and foundation deformations under seismic loading. Letter grading.

Mr. Stewart, Mr. Vucetic (Sp)

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 characterization, geosynthetics, solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading.

Mr. Stewart, Mr. Vucetic (Sp)

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of numerical modeling of geotechnical problems, and to constitutive modeling based on elasticity and plasticity theories. Special emphasis on numerical applications and identification of model limitations and their interpretation. Nonexistence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Not offered 2013-14)

228. Advanced Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 120, 121, 122. Laboratory studies covering more advanced aspects of laboratory deformation of soil properties and their application to design. Tests to determine permeability, consolidation, and shear strength. Review of advanced instrumentation and measurement techniques. Letter grading.

Mr. Vucetic (Not offered 2013-14)

M230A. Linear Elasticity. (4) Same as Mechanical and Aerospace Engineering M236A.) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 156A or 168A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane strain problems; thin plates; stress intensities; constrained stress intensities; beam theory; torsion; shell theory; and matrix methods. Introduction to boundary integral equation method. Letter grading. Mr. Ju, Mr. Mal (F)

M230B. Nonlinear Elasticity. (4) Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course M230A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement rela-
232. Theory of Plates and Shells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Large and deformation theories of thin plates; energy methods; membrane theory of shells; axisymmetric deformations of cylindrical and spherical shells, including bending. Letter grading.

Ms. Zhang (F)


Mr. Taciroglu (Not offered 2013–14)

234. 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 elements, structural analysis, numerical linear algebra, computational 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 force, and displacements; theorems on stationary value of total and complementary potential energy, minimum total potential energy, Maxwell/Beatty theorems, effects of approximations, introduction to finite element analysis. Letter grading. Mr. Taciroglu (W)

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, 235A. Direct energy formulas for deformable systems; solution methods for linear equations; analysis of structural systems with one-dimensional elements; introduction to variational calculus; discrete element displacement, force, and mixed methods for membrane, plate, shell structures; instability effects. Letter grading. Mr. Chen (W)

235C. Nonlinear Structural Analysis. (4) Lecture, four hours; outside study, eight hours. Requisite: course 235B. Classification of nonlinear effects; material nonlinearities; conservative and nonconservative material behavior; geometric nonlinearities, Lagrangian, Eulerian description of motion; finite element methods in geometrically nonlinear problems; post-buckling behavior of structures; solution of nonlinear equations; incremental, iterative, programming methods. Letter grading.

Mr. Ju, Mr. Taciroglu (Not offered 2013–14)


Mr. Jr (Sp)

M237A. Dynamics of Structures. (4) Same as Mechanical and Aerospace Engineering M269B. Lecture, four hours; outside study, eight hours. Requisite: course 137. Principles of dynamics. Determination of normal modes and frequencies by differential and integral equation solutions. Transient and steady state response. Rayleigh’s method and solution of governing equations using matrix formulation. Letter grading. Mr. Bendiksen, Mr. Ju, Mr. Taciroglu (W)

238. Computational Solid Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 137, 141, 235A. Advanced behavior 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 design of beam-column joints. Introduction to displacement-based design and applications of strut-and-tie models. Letter grading.

Mr. Wallace (F)

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 design of 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 behavior and structural integrity of reinforced concrete systems. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, and ductility in design, use of prescriptive versus performance-based design, and evaluation of seismic response of new and existing construction. Letter grading. Mr. Wallace (W)

244. Structural Loads and Safety for Civil Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 141 or 142 or 143 or 144. Modeling of uncertainties in structural loads and structural mechanics; structural safety analysis; and calculation of capacity reduction factors. Letter grading.

Mr. Wallace (W)

245. Earthquake Ground Motion Characterization. (4) Lecture, four hours; outside study, eight hours. Corequisites: course 137 or 246. Earthquake fundamentals, including plate tectonics, fault types, seismic waves, and magnitude scales. Characterization of earthquake source, including magnitude range and rate of future earthquakes. Ground motion prediction equations and site effects on ground motion. Seismic hazard analysis. Ground motion selection and modification for response history analysis. Letter grading.

Mr. Stewert (W)

246. Structural Response to Ground Motions. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 137, 141, 142, 235A. Spectral analysis of ground motions; response, time, and Fourier spectra. Response of structures to ground motions due to earthquakes and explosions. Evaluation of structural response. Response analysis, including evaluation of contemporary design standards. Limitations due to idealizations. Letter grading.

Mr. Yeh (W)

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, and 237A or 246. Concept of seismic isolation, linear theory of base isolation, visco-elastic and visco-plastic behavior, energy recovery and dissipation, compression and bending, buckling of bearings, sliding bearings, passive energy dissipation devices, response of structures with isolation and passive energy dissipation devices, static and dynamic analysis procedures, code provisions and design methods for seismically isolated structures. Letter grading.

Ms. Zhang (Sp)


Mr. Ju (Sp)

249. Selected Topics in Structural Engineering, Mechanics, and Geotechnical Engineering. (2) Lecture, one hour; outside study, eight hours. Senior seminar approach to research problems. Analysis of the results of recent research and developments in structural engineering, structural mechanics, and geotechnical engineering. Structural analysis, finite elements, structural stability, dynamics of structures, structural design, earthquake engineering, ground water, elas ticity, plasticity, structural mechanics, mechanics of composites, constitutive modeling, geomechanics, and geotechnical engineering. May be repeated for credit. S/U grading.

Mr. Brandenberg, Mr. Stewart, Mr. Taciroglu, Mr. Wallace (FW, Sp)

250A. Surface Water Hydrology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150. In-depth study of surface water hydrology, including discussion and interrelationship of major topics such as rainfall and evaporation, soils and infiltration properties, runoff and snowmelt processes. Introduction to rainfall-runoff modeling, floods, and policy issues involved in water resource engineering and management. Letter grading. Mr. Margulis (F)


Mr. Yeh (F)

250C. Hydrometeorology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A. In-depth study of hydrometeorological processes. Role of hydrology in climate system, precipitation and evaporation processes, atmospheric radiation, exchange of mass, heat, and momentum between soil and vegetation surface and overriding 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; optimal timing, sequencing and sizing of water resources projects; and multiojective planning and conjunctive use of surface 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 modeling concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed mod-
eling, parameter estimation and sensitivity analysis, and application of models for flood forecasting and prediction of streamflows in water resource applications. Letter grading. Mr. Marquis (Not offered 2013-14)

251B. Contaminant Transport in Groundwater. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250B, 253. Phenomena and mechanisms of hydrodynamic dispersion, governing equations of mass transport in porous media, various analytical and numerical solutions, determination of dispersivity, laboratory and field experiments, biological and reactive transport in multiphase flow, remediation design, software packages and applications. Letter grading. Mr. Yeh (Not offered 2013-14)

251C. Remote Sensing with Hydrologic Applications. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 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 like topography, soil moisture, snow properties, vegetation, and precipitation. Letter grading. Mr. Marquis (W)

251D. Hydrologic Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisites: coursework on nonlinear filtering. Review of Bayesian and Belief Networks, Kalman Filter, particle filter, ensemble Kalman Filter, lessons from the LightSea, ground truth assimilation. Applications discussed in the context of a groundwater flow model, with specific references to groundwater monitoring and management. Letter grading. Mr. Marquis (Not offered 2013-14)

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 management and renewable resources; 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 20B, Mathematics 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 water treatment. Processes include acid-base chemistry and alkalinity (carbonate system), complexation, precipitation/dissolution, adsorption, ion exchange, and photochemistry. Letter grading. Ms. Jay (F)

255A. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 253A, Chemical kinetics and mass transfer, chemical reaction engineering, coagulation and flocculation, granular filtration, sedimentation, carbon adsorption, gas transfer, disinfection, oxidation, and membrane technology. Letter grading. Mr. Hoek (W)

255B. Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 254A, 255A. Fundamentals of environmental engineering microbiology; kinetics of microbial growth and biological oxidation; applications for activated sludge, gas transfer, fixed-film processes, aerobic and anaerobic digestion, sludge disposal, and biological nutrient removal. Letter grading. Mr. Stenstrom (Sp)

255A. Membrane Separations in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Topics of concentration and separations by reverse osmosis, nanofiltration, ion exchange, and pervaporation. Letter grading. Mr. Hoek (Not offered 2013-14)

259A. Selected Topics in Environmental Engineering. (2) Lecture, four hours; outside study, four hours. Requisite: course 251A. Review of recent research and developments in environmental engineering. Letter grading. Mr. Stolzenbach (FW,Sp)

259B. Selected Topics in Water Resources. (2 to 4) Lecture, four hours; outside study, eight hours. Review of recent research and developments in water resources. Water supply and hydrology, global climate change, water resources planning, estimation of water resources development. May be taken for maximum of 4 units. Letter grading. Mr. Stenstrom (FW,Sp)

260. Advanced Topics in Hydrology and Water Resources. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B, 250D. Current parameter estimation, experimental design, conceptual use of surface and groundwater, multiobjective water resources planning, and optimization of water resource systems. Topics may vary from term to term. Letter grading. Mr. Yeh (Sp)

261. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 254A, 255A. Colloidal interactions, colloidal stability, colloidal dynamics, surface chemistry, adsorption of pollutants on colloidal surfaces, transport of colloids in porous media, coagulation, and particle deposition. Consideration of applications to colloidal processes in aquatic environments. Letter grading. Mr. Hoek (Not offered 2013-14)

261B. Advanced Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255B. In-depth treatment of selected topics related to biological treatment of waters and wastewaters, such as biodegradation of xenobiotics, pharmaceuticals, emerging contaminants, organic solvents, adsorption, 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 well injection, and microbial respiration. Research/modeling project required. Letter grading. Ms. Jay (Sp)

C282. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Correlation, analysis, and prediction of distress mechanisms in pavements, including materials selection and traffic loading and volume. Special attention to aspects of pavement distress such as dowel and full-depth cracking and failure of these into metrics of pavement performance. Discussion of potential causes of pavement distress (i.e., asphalt and concrete) and their specific strengths and weaknesses in particular pavements. Identification and correlation of different variables that influence pavement performance and highlight their relevance in pavement design. Concurrently scheduled with course C283. Letter grading. Mr. CoF (Sp)

296B. Advanced Topics in Civil Engineering. (2 to 4) Seminar, to be arranged. Discussion of current research and literature in research specialty of faculty member teaching course. S/U grading. (FW,Sp)

297. Seminar: Current Topics in Civil Engineering. (2 to 4) Seminar, to be arranged. Lectures, discussions, and student presentations and projects in areas of current interest in civil engineering. May be repeated for credit. S/U grading. (FW,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 presentation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading. (F)

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. May be repeated for credit. S/U grading. (F,W,Sp)

597A. Preparation for M.S. Comprehensive Examination. (2 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 Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate civil 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 civil 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 civil engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

Computer Science

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Mario Gerla, Ph.D.
Richard E. Korff, Ph.D.
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Amit Sahai, Ph.D.
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Stefano Soatto, Ph.D.
Mani B. Srivastava, Ph.D.
Demetri Terzopoulos, Ph.D. (Chancellor's Professor)
Wei Wang, Ph.D.
Alan L. Yuille, Ph.D.
Carlo A. Zaniolo, Ph.D. (Norman E. Friedman Professor of Knowledge Sciences)
Lixia Zhang, Ph.D. (Jonathan B. Postel Professor of Computer Systems)
Song-Chun Zhu, Ph.D.

Professors Emeriti
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Michel A. Melkanoff, Ph.D.
Richard R. Muntz, Ph.D.
Judea Pearl, Ph.D.
David A. Rennels, Ph.D.
Jacques J. Vidal, Ph.D.

Associate Professors
Junghoo (John) Cho, Ph.D.
Eleazar Eskin, Ph.D.
Todd D. Millstein, Ph.D.
Glenn D. Reinman, Ph.D.
Yuval Tamir, Ph.D.

Assistant Professors
Tyson Condie, Ph.D.
Jason Ernst, Ph.D.
Alexander Sherstov, Ph.D.
Zhouchen Tu, Ph.D.
Jennifer W. Vaughan, Ph.D. (Symantec Term Professor of Computer Science)

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

Adjunct Professors
David E. Heckerman, Ph.D.
Van Jacobson, Ph.D.
Alan C. Kay, Ph.D.
Rupak Majumdar, Ph.D.
Peter S. Pao, Ph.D.
Peter L. Reiner, Ph.D.
M. Yahya Sanadidi, Ph.D.

Adjunct Associate Professors
Edward W. Kohler, Ph.D.
Giovanni Pau, Ph.D.

Adjunct Assistant Professors
Carey S. Nachenberg, M.S.
Ani Nahapetian, Ph.D.

Visiting Assistant Professor
Louis-Noel Pouchet, 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 the 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 bioinformatics, 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, bioinformatics, 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 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 either a software engineering or major product design course, while Computer Science 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 10; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, 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,

Computer Science students work with an autonomous maze-solving micromouse robot as an exercise of skills in circuit design, microcontroller programming, circuit debugging, feedback control, and sensor fusion.
Preparation for the Major

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

The Major

Required: Computer Science 111, 118, 131, M151B (or Electrical Engineering M16C), M152A (or Electrical Engineering M16L), 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 five upper division computer science elective courses (20 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); 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 18 or http://www.registrar.ucla.edu/ge/.

Computers 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.

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), (2) have completed at least two of the lower division requirements with minimum grades of C, and (3) file a petition in the Office of Academic and Student Affairs of the Henry Samueli School of Engineering and Applied Science, 6426 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 (or Computer Science M184), Computer Science 180 (or Mathematics 182), two courses from Computer Science CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130 (unless taken as a required course), 132, 133, 136, 143, 144, 151C, 152B (unless taken as a required course), 161, 170A, M171L (or Electrical Engineering M171L), 174A, 174B, C174C, 183, M184 (or Bioengineering M184 or Computational and Systems Biology M184), Computer Science 186, Computional and Systems Biology M186, two courses from Computer Science 187 (or Bioengineering M187 or Computational and Systems Biology M187). If students have not taken Computer Science 130, one elective course 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 18 or http://www.registrar.ucla.edu/ge/.
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 22. The following introductory information is based on the 2013-14 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 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, 101A, 102, 103, 110L, M116L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 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 of 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 School-wide 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 advisor, must be explicitly acknowledged in detail. Prior to submission, the paper must be reviewed by the student’s advisor on a cover page with the advisor’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 network 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, queuing theory, distributed systems theory, mathematical programming, control theory, operating systems design, simulation methods, measurement tools, and heuristic design procedures. 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 division 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 internationally to a certain body of knowledge emphasizing the intertwining 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 how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), how efficiently a proposed system performs a task in terms of resources used, and 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 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

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<th>Emphasis of Computer Science Theory</th>
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<tr>
<td>• Design and analysis of algorithms</td>
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<td>• Distributed and parallel algorithms</td>
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<td>• Models for parallel and concurrent computation</td>
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<td>• Online and randomized algorithms</td>
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<td>• Computational complexity</td>
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<td>• Automata and formal languages</td>
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<td>• Cryptography and interactive proofs</td>
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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, 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), network-on-a-chip (NoC), system-in-a-package (SiP), 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:
oped 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/hcii/.

**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.

**W. M. Keck Laboratory for Computer Vision**

The laboratory, sponsored by a grant from the W. M. Keck Foundation, hosts a variety of high-end equipment for vision research including a full 360-degree light dome, 3-D laser scanners, cameras, lights, lenses, mobile robots, and virtual reality setup to support vision research in the departments of Statistics, Computer Science, Psychology, and Neuroscience.

**MAGIX: Modeling Animation and Graphics Laboratory**

The MAGIX Modeling Animation and Graphics Laboratory is used for research on computer graphics, especially targeted towards the video game and motion picture industries, with emphasis on geometric, physics-based, and artificial life modeling and animation, including motion capture techniques, biomechanical simulation, behavioral animation, and graphics applications of machine learning, AI, and robotics. See http://www.magix.ucla.edu.

**UCLA Collective on Vision and Image Sciences**


**UCLA Vision Laboratory**

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.

**Computer Networks Laboratories**

**CENS Systems Laboratory**

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.

**Computer Communications Laboratory**

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

**High-Performance Internet Laboratory**

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/hp/.

**Internet Research Laboratory**

The Internet Research Laboratory (IRL) 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.

**Network Research Laboratory**

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/.

**Computer Science Theory Laboratories**

**Center for Information and Computation Security (CICS)**

The Center for Information and Computation Security (CICS) promotes all aspects of research and education in cryptography and computer security. See http://www.cs.ucla.edu/security/.

**Theory Laboratory**

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.

**Computer Systems Architecture Laboratories**

**Concurrent Systems Laboratory**

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/csdl/research/labs/csl/.

**Digital Arithmetic and Reconfigurable Architecture Laboratory**

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

**Embedded and Reconfigurable System Design Laboratory**

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.

**VLSI CAD Laboratory**

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.

Information and Data Management Laboratories

Data Mining Laboratory
The Data Mining Laboratory is used for extraction of patterns, anomalies, concepts, classification rules, and other forms of high-level relationships that are latent in large commercial and scientific databases. See http://www.dml.cs.ucla.edu.

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.mmss.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://pocl.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
JingSheng Jason 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 J. 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 animal-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

* Also Professor of Medicine
sensor networks, Internet transport protocols (TCP, streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocol performance evaluation
Christopher J. Lee, Ph.D. (Stanford, 1993) Bioinformatics and information theory of experiment planning, inference, and evolution
Songwu Lu, Ph.D. (Illinois, 1990) Integrated-service support over heterogeneous networks, e.g. mobile computing environments, Internet and ActiveNet: networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics
* Rafael Ostrovsky, Ph.D. (MIT, 1992) Theoretical computer science algorithms, cryptography, complexity theory, randomization, network protocols, geometric algorithms, data mining
Jens Palsberg, Ph.D. (UC Berkeley, 1991) Compiler, embedded systems, programming languages
D. Stott Parker, Jr., Ph.D. (Illinois, 1978) Data mining, information modeling, scientific computing, bioinformatics, database and knowledge-based systems
Modrag Potkonjak, 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
Amit Sahai, Ph.D. (MIT, 2000) Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory
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: reconstruction; statistical shape analysis; autonomous systems: sensor-based control, planning non-linear filtering; human-computer interaction: vision-based interfaces, virtual reality
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
Alfred A. Avizienis, Ph.D. (Illinois, 1960) Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multiprocessor/multithreaded processor design
Yuval Tamir, Ph.D. (UC 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
Eleazar Eskin, Ph.D. ( typeof the problem, the method used to solve it, the data structures and algorithms used) Bioinformatics, genetics, genomics, machine learning

Associate Professors
Tarek Mittleman, Ph.D. (U. Washington, 2003) Programming language design, static and dynamic type systems, formal methods, software model checking, compiler
Glenn D. Reinman, Ph.D. (UC San Diego, 2001) Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multiprocessor/multithreaded processor design

Senior 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

Senior Lecturer S.O.E. Emeritus
Leon Levine, M.S. (MIT, 1949) Computer methodology

Adjunct Professors
David E. Heckerman, Ph.D. (UCLA, 1979) Models and methods used for statistics and data analysis, machine learning, probability theory, decision theory, design of HIV vaccines, and genome-wide association studies

Named data network (NDA), content-centric networking
Alan Kay, Ph.D. (Utah, 1969) Object-oriented programming, personal computing, graphical user interfaces
Rupak Majumdar, Ph.D. (UC Berkeley, 2003) Computer-aided verification of hardware and software systems; logic and automata theory; embedded, hybrid, and probabilistic systems

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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, strings, pointers, object-oriented programming. Examples and exercises from computer science theory and applications. Letter grading. Mr. Palsberg, Mr. Smallberg (FW,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. Processors: CPU, caches, 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. Smallberg (FW)

551A. Logic Design of Digital Systems. (4) (Same as Electrical Engineering M161) Lecture, four hours; discussion, two hours; outside study, six 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. Gerla, Ms. Vaughan (F,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 (wireless and wired). Focus on wireless communications and media access layers of network protocol stack. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environmental awareness, and experimental laboratory sessions included. Letter grading. Mr. Gerla (W)

118. Computer Network Fundamentals. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 31, 32, 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. Gerla, Ms. Zhang (FW,Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Enforced requisites: courses 32 or Program in Computing 103C or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from the biological or medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on analysis, clustering, and align algorithms. Concurrently scheduled with course CM221. P/NP grading.

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 103C with grade of C– or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A.

Bioinformatics

Lower Division Courses

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, six to 12 hours. Limited to juniors/seniors. Supervised individual research under guidance of faculty mentor. Culminating paper required. May be repeated. P/NP grading.

Upper Division Course

199. Directed Research in Bioinformatics. (2 to 4) Tutorial, six to 12 hours. Limited to juniors/seniors. Supervised individual research under guidance of faculty mentor. Culminating paper required. May be repeated for credit. Individual contract required. Letter grading.

Computer Science

Lower Division Courses

1. Freshman Computer Science Seminar. (1) Seminar, one hour; discussion, one hour. Introduction to departmental 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. Palsberg (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.

10. 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.

111. Operating Systems Principles. (5) Lecture, four hours; laboratory, two hours; outside study, nine hours. Enforced requisites: courses 32, 33, 35L. Introduction to operating systems design and evaluation. Computer software systems performance, robustness, and functionality. Kernel structure, bootstrapping, input/output (I/O) devices and interrupts. Processes and threads; address spaces, memory management, and virtual memory. Scheduling, synchronization. File systems: layout, performance, robustness. Distributed systems; networking, remote procedure call (RPC), asynchronous RPC, distributed file systems, transactions. Protection and security. Exercises involving applications using, and internals of, real-world operating systems. Letter grading. Mr. Eggert (FW,Sp)

112. Modeling Uncertainty in Information Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: Statistics 100A. Designed for juniors/seniors. Provides a stochastic and stochastic process models as applied in computer science. Basic methodological tools include random variables, conditional probability, expectation and higher moments, Bayes theorem. Applications include probabilistic algorithms, evidential reasoning, analysis of algorithms and data structures, reliability, communication protocol and queuing models and network grading.

114. Peer-to-Peer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 118. Recommended requisite: course 111. Optional: course 218. Fundamental concepts on peer-to-peer networks, such as distributed hash-tables, routing, searching, and related network management protocols (Join, Leave, death management, routing, table repair). Video streaming and Internet Protocol’s (IP) applications. With emphasis on thin clients such as PDAs and smart phones. Introduction to mesh-based and tree-based topologies for live streaming, with emphasis on key aspects of peer selection. Virtualisation of common 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)

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. Focus on wireless communications and media access layers of network protocol stack. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environment awareness, and experimental laboratory sessions included. Letter grading.

118. Computer Network Fundamentals. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 31, 32, 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. Gerla, Ms. Zhang (FW,Sp)
Course CM121 is not requisite to CM122. Designed for engineering students as well as students from biologic al sciences and medical school. Introduction to computational analysis of genetic variation and computer science. Concurrently scheduled with course CM224. Letter grading.

Mr. Eskin (Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: courses 32, 33L. Recommended: Mathematics 170A or Statistics 100A. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genetic variation and computer science. Concurrently scheduled with course CM224. Letter grading.

Mr. Cho (F)

M151B. Computer Systems Architecture. (4) (Same as Electrical Engineering M151B.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 33, and M51A or Electrical Engineering M16. Recommended: courses 111, and M152A or Electrical Engineering M16L. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output, interrupts and exceptions, DMA, evaluation performance, pipelined processors. Letter grading.

Mr. Reinman, Mr. Tamir (W,Sp)


Mr. Furst (W,Sp)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical Engineering M151B.) Laboratory, four hours; outside study, six hours. Enforced requisite: course M51A or Electrical Engineering M16. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation. Implementation of complex circuits using programmed array logic, design projects. Letter grading.

Mr. Sarraffzadeh (F,Sp)

M152B. Digital Design Project Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M51B or Electrical Engineering M16B. Recommended: Engineering 183EW or 185EW. Limited to seniors. Design and implementation of complex digital subsystems using field-programmable gate arrays (e.g., processors, special-purpose processor controllers, and input/output interfaces). Students work in teams to develop and implement designs and to document and give oral presentations of their work. Letter grading.

Mr. Sarraffzadeh (F,Sp)


Mr. Parker (W)

M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Electrical Engineering M171L.) Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: course M152A. Limited to seniors. Not open to students with credit for course M117. Interpretation of analog-signaling aspects of digital systems and data communication through experience in using temporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem and terminal characteristics, and interfaces. Letter grading.

Mr. LeNepveu (W,Sp)

174A. Introduction to Computer Graphics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 32. Basic principles behind modern two- and three-dimensional computer graphics systems, including complete set of steps that modern graphics pipelines use to create realistic images in real time. How to position and manipulate objects in scene using geometric and camera transformations. How to create final image using perspective and orthographic transformations. Basics of modeling primitives such as polygonal models and implicit and parametric ideas behind color spaces, illumination models, shading, and texture mapping. Letter grading.

Mr. Soatto (F,Sp)

174B. Introduction to Computer Graphics: Three-Dimensional Photography and Rendering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. State of art in three-dimensional photography and image-based rendering. How to use cameras and light to capture shape and appearance of real objects and scenes. Process provides simple way to acquire three-dimensional models of unparalleled detail and realism. Applications of techniques from entertain ment (requiring engineering of scenes from movies, generation of realistic synthetic objects and characters) to medicine (modeling of biological structures from imaging data), mixed reality (augmentation of video), and security (visual surveillance). Fundamental analytical tools for modeling and inferring geometric (shape) and photometric (reflectance, illumination) properties of objects and scenes, and for rendering and manipulating novel views. Letter grading.

Mr. Soatto (Not offered 2013-14)

C174C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 32. Recommended for juniors/seniors. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture and animation of physics-based animation of particles and systems, and motor control. Concurrently scheduled with course C274C. Letter grading.

Mr. Terzopoulos (Not offered 2013-14)


Mr. Gafni (F,Sp)

181. Introduction to Formal Languages and Automata Theory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 32, and Mathematics 61 or 180. Designed for junior/senior Computer Science majors. Automata, languages, and grammars. Finite-state languages and finite-state automata. Context-free languages and pushdown story automata, unrestricted rewriting systems, recursively enumerable and recursive languages, and Turing machines. Closure
properties, pumping lemmas, and decision algo-
rithms. Introduction to computability. Letter grading.
Mr. Ostrovsky, Mr. Sahai (Sp)

183. Introduction to Cryptography. (4) Lecture, four
hours; discussion, two hours; outside study, six
hours. Preparation: knowledge of basic probability
theory. Enforced requisite: course 180. Introduction
to cryptography, complexity theory, and basic con-
cepts and techniques. Topics include notions of
hardness, one-way functions, hard-core bits, pseudo-
random generators, pseudorandom functions and
permutations, semantic security, public-key and private-
key encryption, key-agreement, homomorphic encryp-
tion, private information retrieval and voting protocols, message authentic-
tion, digital signatures, interactive proofs, zero-
knowledge proofs, collision-resistant hash functions, commitment protocols, and two-party secure com-
puting with static security. Letter grading.
Mr. Ostrovsky (not offered 2013–14)

M184. Introduction to Computational and Sys-
tems Biology. (2) Formerly numbered M186A.
(Same as Bioengineering M184 and Computational
and Systems Biology M184.) Lecture, two hours; out-
side study, four hours. Preparation: completion of
I. Introduction. Introduction to computational and sys-
tems modeling and computa-
tion in biology and engineering, providing software,
modeling techniques, and an introduction to
flavor, culture, and cutting-edge contributions in
computational biosciences and aiming for more in-
focused basis for focused studies by students with
computational and systems biology interests. Pre-
sentations by individual UCLA researchers discuss-

Graduate Courses

201. Computer Science Seminar. (2) Seminar, four
hours; outside study, two hours. Designed for gradu-
techniques in computer science. May be repeat-
ed for credit. S/U grading.

202. Advanced Computer Science Seminar. (4)
Seminar, four hours; outside study, eight hours.
Preparation: coursework in computer science. Current computer science re-
search into theory of, analysis and synthesis of, and
applications of information processing systems. Each member of the class will present one or more
original pieces of work in one specialized area. May
be repeated for credit. Letter grading.
Ms. Estrin

211. Network Protocol and Systems Software De-
sign for Wireless Internet. (4) Lecture, four
hours; outside study, eight hours. Requisite:
course 118. Designed for graduate students. In-
depth study of protocol network and systems soft-
ware 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 comput-
ing systems software: middleware, file system, ser-
vices, and applications, and (4) topical studies: ener-
gy-efficient design, security, location management,
and quality of service. Letter grading.
Mr. Lu

212A. Queueing Systems Theory. (4) Lecture, four
hours; outside study, eight hours. Requisites: course
112, Electrical Engineering 131A. Resource sharing
issues and theory of queueing-line systems. Review
of Markov chains and baby queueing theory.
Method of stages. M/E/1, E/M/1. Bulk arrival and
bulk service systems. Series-parallel stages. Funda-
mentals of open and closed queueing networks.
In-
terference, queuing theory, collision models, G/G/M,
simulations, and numerical techniques. Advanced
queueing theory: G/G/1; Lind-
ley integral equation; spectral solution. Inequalities,
bounds, approximations.
Letter grading.
Mr. Gerla

212B. Queueing Applications: Scheduling Algo-
rithms and Queuing Networks. (4) Lecture, four
hours; outside study, eight hours. Requisite: course
212A. Priority queueing. Applications to time-sharing
scheduling algorithms: FB, Round Robin, Conserva-
tion Law, Bounds. Queueing networks: definitions;
job flow balance; product form solutions—local bal-
ance, M/M/1, computational algorithms for perfor-
mane measures: asymptotic behavior and bounds;
approximation techniques—diffusion—iterative tech-
niques; applications. Letter grading.
Mr. Muntz

M213A. Embedded Systems. (4) [Same as Electrical
Engineering M202A] Lecture, four hours; outside
study, eight hours. Requisite: course 111. Designed
for graduate computer science and electrical engi-
eering students. Methodologies and technologies for
design of embedded systems. Topics include hard-
ware and software platforms for embedded sys-
tems, techniques for modeling and specification of
system behavior, software organization, real-time op-
erating system scheduling, real-time communication
and packet scheduling, low-power battery and ener-
gy-aware system design, timing synchronization, fault
tolerance and debugging, and techniques for hard-
ware and software architecture optimization. Theoret-
cal foundations as well as practical design methods.
Mr. Potkonjak

M213B. Energy-Aware Computing and Cyber-
Physical Systems. (4) [Same as Electrical Engineer-
ing M202B] Lecture, four hours; outside study, eight
hours. Requisite: course M51A or Electrical Engineer-
ing M151Arecommended: courses 111, and M151B
or Electrical Engineering M116C. System-level man-
agement and cross-layer methods for power and en-
ergy consumption in computing and communication at
various scales ranging across embedded, mobile,
personal, enterprise, and data-center scale. Comput-
ing, networking, sensing, and control technologies
and algorithms for improving energy sustainability in
human-cyber-physical systems. Topical covered
including energy consumption, energy sources, and
energy storage; dynamic power management; pow-
er-performance scaling and energy proportionality;
dynam-icy-cycling; aware scheduling; low-power proto-
ocols; battery modeling and management; ther-
mal management; sensing of power consumption.
Letter grading.
Ms. Estrin, Mr. Srivastava

214. Data Transmission in Computer Commu-
nication Networks. (4) Lecture, four hours; outside study, eight
hours. Requisite: course 112. Limited to graduate computer science students. Discrete data streams,
formats, rates, transmissions; digital data transmis-
sion via analog signaling; communication theory;
media characteristics, system methodologies, perfor-
manee analysis; modern designs; physical in-
terfaces in computer communication links; national/
international standards; tests and measurements.
Letter grading.
Mr. Carlyle

215. Computer Communications and Net-
works. (4) Lecture, four hours; outside study, eight
hours. Requisite: course 112. Resource sharing/computer traffic characterization; multiplexing; network struc-
ture; packet switching and other switching tech-
niques; ARAPNET and other computer network ex-
amplars; network design and optimization; network protocols; routing and flow control; satellite and ground radio packet switching; local networks; commercial network services and ar-
chitectures. Optional topics include extended error
control techniques; modern; SDLC, HDLC, X.25,
etc.; protocol verification; computer simulation and
measurement; integrated networks; communication processes. Letter grading.
Mr. Chu

216. Distributed Multicore Control in Networks. (4)
Lecture, four hours; outside study, eight hours.
Requisites: courses 212A, 215. Topics from field of
distributed control and access in computer networks,
including application and distributed control; satellite
packet switching; ground radio packet switching;
local network architecture and control.
Letter grading.
Mr. Kleinrock

217A. Internet Architecture and Protocols. (4)
Lecture, four hours; outside study, eight hours. Requisite:
course 118. Focus on mastering existing core set of
Internet protocols, including IP, core transport proto-
cols, routing protocols, DNS, NTP, and security pro-
tocols such as DNSSec, to understand principles
behind design of these protocols, appreciate their
design tradeoffs, and learn lessons from their opera-
tions. Letter grading.
Ms. Zhang (W)

217B. Advanced Topics in Internet Research. (4)
Lecture, four hours; outside study, eight hours. Requir-
e: course 217A. Designed for graduate students.
Overview of Internet development history and funda-
mental principles underlying TCP/IP protocol design.
Discussion of current Internet research topics, includ-
ing latest research results in routing protocols, trans-
port protocols, network measurements, network se-
curity protocols, and clean-slate approach to network
architecture design. Fundamentals of network proto-
ocol design and implementations. Letter grading.
Ms. Zhang (Sp)

218. Advanced Computer Networks. (4) Lecture,
four hours; outside study, eight hours. Requisites:
courses 112, 118. Review of seven-layer ISO-OSI

219. Current Topics in Computer System Modeling Analysis. (4) Lecture, four hours; outside study, four hours. Review of current literature in area of computer system modeling analysis in which instructor has expertise as continuation of current and previous research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading.

Ms. Estrin, Mr. Liu (W)

CM221. Introduction to Bioinformatics. (Same as Bioinformatics M228A, Chemistry CM269A, and Human Genetics M260A.) 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. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of biological sequences and applications to biological questions, with focus on developing algorithms to compare biological sequences. Concurrency scheduled with course CM121, S/U or letter grading.

Mr. Eskin (F)

CM222. Algorithms in Bioinformatics and Systems Biology. (Same as Bioinformatics M224 and Human Genetics CM262.) 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 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 computational techniques. Computational techniques include those from statistics and computer science. Concurrency scheduled with course CM122. Letter grading.

Mr. Eskin CM224. Computational Genetics. (Same as Bioinformatics M222 and Human Genetics CM224.) Lecture, four hours; discussion, two hours; outside study, six 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. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genetic sequences and computational inter- genetic research. Topics include introduction to genetic analysis, identification of genes involved in disease, inferring human population history, technologies for obtaining genetic information, and genetic sequence analysis. Focus on formulating interdisciplinary problems as computational problems and then solving those problems using computational techniques from statistics and computer science. Concurrency scheduled with course CM124. Letter grading.

Mr. Eskin (Sp)

M229S. Seminar: Current Topics in Bioinformatics. (4) (Same as Biological Chemistry M229S and Human Genetics M229S.) Seminar, four hours; outside study, six hours. Recommended for graduate students in engineering students, as well as students from biological sciences and medical school. Introduction to current topics in bioinformatics, genomics, and computational genomics. Emphasis on computational interdisciplinary research in genetics and genomics. Topics include genome analysis, regulatory genomics, association analysis, association study design, isolated and amplified expression data analysis, computational substructure, human structural variation, model organisms, and genomic technologies. Computational techniques include those from statistics and computer science. May be repeated for credit with topic change. Letter grading.

Mr. Eskin (Sp)

230A. Models of Information and Computation. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: courses 131, 181. Paradigms, models, frameworks, and problem solving: UML and meta-modeling; basic information and computation models; axiomatic systems; domain theory; least fixed points, denotational semantics, operational semantics; sentences, axioms and rules, normal forms, derivation and proof, models and semantics, propositional logic, first-order logic, logic programming. Functional models: expressions, equations, evaluation; combinatorics, lambda calculus, unification, narrowing. Program models: program derivation and verification using Hoare logic, object models, standard templates, design patterns, meta-programming. Letter grading.

Mr. Bagrodia, Mr. Parker, Mr. Zaniolo

231. Types and Programming Languages. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Introduction to static type systems and their use in verifying design specifications and software reliability. Operational semantics, simply-typed lambda calculus, type soundness proofs, types for mutable references, types for exceptions. Parametric polymorphism, let-polymorphism, polymorphic type inference. Types for objects, subtyping, combining parametric polymorphism and subtyping. Types for modules, parameterized modules. Formal specification and implementation of variety of type systems, as well as readings from recent research literature on modern applications of type systems. Letter grading.

Mr. Millstein (F)

232. Static Program Analysis. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Introduction to static analysis of object-oriented programs and its usage for optimization and bug finding. Class hierarchy analysis, rapid type analysis, equality-based analysis and specialization, insensitve and sensitive analysis, insensitve and flow-sensitive analysis, context-insensitive and context-sensitive analysis. Soundness proofs for static analyses. Efficient data structures for static analysis information such as directed graphs and binary decision diagrams. Flow-directed method inlining, type-safe method inlining, synchronization analysis, deadlock detection, security vulnerability detection. Formal and implementation of variety of static analyses, as well as readings from recent research literature on modern applications of static analysis. Letter grading.

Mr. Palasberg

233A. Parallel Programming. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 131. Mutual exclusion and resource allocation in distributed systems; primitives for parallel computation: specification of parallelism, interprocess communication and synchronization, atomic actions, binary and multiway rendezvous; synchronous and asynchronous languages: CSP, Ada, Linda, Maisie, UC, and others; introduction to parallel program verification. Letter grading.

Mr. Cong

233B. Verification of Concurrent Programs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 233A. Formal techniques for verification of concurrent programs. Topics include safety, liveness, program and state assertion-based techniques, weakest precondition semantics, Hoare logic, temporal logic, UNITY, and axiomatic semantics for selected parallel languages. Letter grading.

Mr. Bagrodia

234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Introduction to theory and practice of formal methods for analysis of concurrent and embedded systems, with focus on algorithmic 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 Parallel Algorithms. (4) Lecture, four hours. Preparation: C or C++ programming experience. Requisite: course 111. In-depth investigation of operating systems issues through guided construction and implementation of operating system for PC machines and consideration of recent literature. Memory management and protection, interrupts and traps, processes, interprocess communication, preemptive multitasking, file systems. Virtualization, networking, profiling, research operating systems. Series of laboratory projects, including extra challenge work. Letter grading. Mr. Millstein (Sp 2013-14)

236. Computer Security. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 118. Basic and research material on computer security. Topics include basic principles and goals of computer security, history and use of cryptography; protocols for security, security tools (firewalls, virtual private networks, honeypots), virus and worm protection, security assurance and testing, design of secure programs, privacy, applying security principles to realistic problems, and new and emerging threats and security tools. Letter grading.

Mr. Palisberg, Mr. Reiher

239. Current Topics in Computer Science: Introduction to current literature in area of computer science. Letter grading. Mr. Millstein (Sp)

240A. Databases and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143. Theoretical and technological foundation of Intelligent Database Systems, that merge database technology, knowledge-based systems, and advanced programming environments. Knowledge representation, spatio-temporal reasoning, and logic-based declarative querying/programming are salient features of this technology. Other topics include object-relational systems and data manipulation, object-oriented databases and nonmonotonic reasoning. Temporal queries, spatial queries, and uncertainty in deductive databases and object relational databases (ORDBs). Abstract data types and type definitions in functional ORDBs. Data mining algorithms. Semistructured information. Letter grading.

Mr. Parker, Mr. Zaniolo (Sp)


Mr. Palisberg, Mr. Zaniolo (Sp)

241A. Object-Oriented and Semantic Database Systems. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Object database principles and requirements. Data models, accessing and query language design, query functionality and functional management standards. Extended relational-object systems. Database systems architecture and functional components. Systems comparison. Commercial products, database design and indexing, and performance. Future directions. Other topics at discretion of instructor. Letter grading. Mr. Cardenas

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 across Internet by alphanumeric, image, video, and audio content. Querying, visual languages, and construction of multimedia data. Databases and multimedia data management standards. Extended relational-object systems. Database systems architecture and functional components. Systems comparison. Commercial products, database design and indexing, and performance. Future directions. Other topics at discretion of instructor. Letter grading. Mr. Cardenas

244A. Distributed Database Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 215 and/or 241A. File allocation, intelligent directory design, transaction management, deadlock, strong and weak concurrency control, commit protocols, recovery mechanisms, fault recovery techniques, network partitioning, examples, trade-offs, and design experiences. Letter grading.

Mr. Otis

245A. Intelligent Information Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 241A, 255A. Knowledge discovery in database, knowledge-base maintenance, knowledge-
base and database integration architectures, and scale-up issues and applications to cooperative database systems and principles for their management and retrieval. Study of Web characteristics and new management technologies needed to build computer systems suitable for Web environment. 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. Review of current literature in area of data structures in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading. Mr. Parker (Sp)

251A. Advanced Computer Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course 151B. Recommended: course 111. Design and implementation of high-performance systems, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW processors, branch prediction and speculation, execution, instruction format, software support for instruction-level parallelism, simulation-based performance analysis and evaluation, state-of-art design examples, introduction to parallel architectures. Letter grading.

Mr. Ercegovac, Mr. Tamir (F)

251B. Parallel Computer Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 151B. Recommended: course 251A. SIMD and MIMD systems, symmetric multiprocessors, distributed-shared-memory systems, messages-passing systems, multicores, clusters, interconnected networks, host-network interfaces, switching elements. Letter grading.

Mr. Ercegovac, Mr. Tamir (F)

252A. Arithmetic Algorithms and Processors. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Number systems: conventional, redundant, signed-digit, and residue. Types of algorithms and implementation of addition, subtraction, multiplication, and division. Floating-point arithmetic. Letter grading.

Mr. Ercegovac, Mr. Tamir (F)

252B. Computer Arithmetic Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252A. Computer arithmetic algorithms, including mathematical operations, floating-point, and fixed-point representations. Letter grading.

Mr. Ercegovac, Mr. Tamir (F)

254A. Computer Memories and Memory Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252B. Design and implementation of memory systems; control, access modes, hierarchies, and allocation algorithms. Characteristic, systems organization, and device considerations for ferro and magnetic memories, semiconductor memories, and memory systems. Letter grading.

Mr. Chu

255A. Distributed Processing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 215 and/or 251A. Task partitioning and allocation, interprocess communications, task response time model, process scheduling, message passing protocols, replicated file systems, interface, cache memory, actor model, fine grain multicomputers, distributed operating system kernel, error recovery strategy, performance monitoring and measurement, scalability and maintainability, and commercial distributed systems. Letter grading.

Mr. Chu

256A. Advanced Scalable Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251B. Recommended: course 251A. State-of-art scalable multiprocessors. Interdependency among instrumentation hardware for architecture, memory access network, and system architecture. Performance and power analysis. Letter grading.

Mr. Chu

258A. Design of VLSI Circuits and Systems. (4) Same as Electrical Engineering M216A.) Lecture, four hours; discussion, laboratory, four hours; outside study, three 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.

Mr. Tamir (W)

259C. LSI in Computer System Design. (4) (Same as Electrical Engineering M216C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M258A. LSI/VLSI design and application in computer systems. In-depth study of VLSI architectures and VLSI design tools. Letter grading.

Mr. Ercegovac, Mr. Tamir (F)

259E. Foundations of VLSI CAD Algorithms. (4) Lecture, four hours; outside study, eight hours. Preparation: one or more graduate courses in algorithms. Basic theory of combinatorial optimization for VLSI physical layout, including mathematical programming, network flows, matching, greedy and heuristic methods, and stochastic methodologies. Emphasis on practical application to computer-aided physical design of VLSI circuits at high-level phases of layout: partitioning, placement, graph folding, floorplanning, and global routing. Letter grading.

Mr. Cong

259F. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Detailed study of various physical design automation problems of VLSI circuits, including logic partitioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven layout. Applications of optimizers and important optimization techniques, such as network flows, Steiner trees, simulated annealing, and generic algorithms. Letter grading.

Mr. Cong

259G. 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; multilevel Boolean network optimization; technology mapping for standard cell designs and field-programmable gate-array (FPGA) designs; timing for sequential circuits; and applications of binary decision diagrams (BDDs). Letter grading.

Mr. Cong

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requisite: course 258A. Detailed study of various problems in analysis and design of high-speed VLSI interconnects at both integrated circuit (IC) and packaging levels, including interconnect capacitance and resistance, crosstalk and loss, and transmission line equivalent circuits, fluctuation noise, delay models, and power dissipation models. Interconnect topology and geometry optimization, and clocking for high-speed systems. Letter grading.

Mr. Cong

259. Current Topics in Computer Science: System Design/Architecture. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer science system design 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.

Mr. Cho (Sp)

260. 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 PAC learning theory, VC dimension, online learning, no-regret learning, online convex optimization, ensemble methods and boosting, and connections to gambling. 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 using belief networks representation. Letter grading.

Mr. Darwiche (W)


Mr. Pearl


Mr. Pearl

262Z. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 262A. Additional requisites for each offering announced in advance by department. Theor and implementation of systems that emulate or support human reasoning. Current literature in artificial intelligence, and individual studies in artificial intelligence, knowledge-based systems, decision support systems, computational psychology, and heuristic programming theory. May be repeated for credit with topic change. Letter grading.

Mr. Pearl
263A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161 or 161H. Introduction to natural language processing (NLP), with emphasis on semantics. Presentation of process models for variety of tasks, including question answering, paraphrasing, machine translation, word-sense disambiguation, narrative and editorial generation. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading. Mr. Dyer (W)

263B. Connectionist Natural Language Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 161 or 263A. Examination of connectionist/ANN architectures designed for natural language processing. Issues include localist versus distributed representation, variable binding, instruction and inference via spreading activation, acquisition of language and world knowledge (for instance, via back propagation in PDP networks and competitive learning in self-organizing feature maps), and grounding of symbols in sensory/motor experience. Letter grading. Mr. Dyer

263C. Animals-Based Modeling. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Animals are mobile/sensing animal-like software agents embedded in simulated dynamic environments. Emphasis on modeling: goal-oriented behavior via neurocontrollers, adaptation via reinforcement learning, evolutionary programming. Animat-based tasks include foraging, mate finding, predation, navigation, predator avoidance, cooperative nest construction, communication, and parenting. Letter grading. Mr. Dyer (F)

264A. Automated Reasoning: Theory and Applications. (4) Lecture, four hours; laboratory, four hours; outside study, four 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 satisfiability and entailment; and semantic restrictions on knowledge bases; effect of these restrictions on expressiveness, compactness, and computational tractability; applications of automated reasoning to diagnosis, planning, design, formal verification, and reliability analysis. Letter grading. Mr. Darwiche (Sp)


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 for statistical inference and learning that could be used in vision, pattern recognition, speech, bioinformatics, data mining. Topics include Markov chain Monte Carlo methods, 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 and do in-class research in one area of interest. Letter grading. Mr. Vidal

267B. Artificial Neural Systems and Connectionist Computing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 267A. Examination of major connectionist computing paradigms and underlying models of biological and physical processes. Examination of past and current implementations of artificial neural networks along with their applications. Analysis of major connectionist computing paradigms and underlying models of biological and physical processes. Letter grading. Mr. Vidal (F)


268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Design and analysis of simple models of complex systems. Analysis of advanced topics and current research in computational neuroscience. Letter grading. Mr. Terzopoulos (Sp)

270A. Computer Methodology: Advanced 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 algebra, analysis, approximation, and statistics, data acquisition and reduction: emphasis on concepts pertinent to modeling and simulation and applicability of contemporary developments in numerical software. Computer exercise. Letter grading. Mr. Soatto, Ms. Vaughan (W,Sp)


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. Students present research papers from among others) simulation languages, dataflow machines, array processors, and advanced mathematical modeling techniques. Topics vary each term. May be repeated for credit with topic change. Letter grading.

272. Advanced Discrete Event Simulation and Modeling Techniques. (4) Lecture, four hours; outside study, eight hours. In-depth study in discrete event simulation and modeling techniques, including simulation of computer and communication systems, output analysis of systems, comparisons of alternative system configurations. Variance reduction techniques, simulation models of computer systems and manufacturing systems. Letter grading.


C274C. Computer 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, rigid and deformable bodies, collision of particles and systems, and motor control. Concurrently scheduled with course C174C. Letter grading.

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 174A. Recommended: course 174E. Investigation of important role that computer graphics plays in simulations of life. First look at how computer simulation that spans computational and biological sciences, can play in construction of advanced computer graphics and vision models for virtual reality, animation, interactive gaming, and vision, as well as 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. Examine 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 learning of locomotion, cognitive modeling, artificial animals and humans, human facial animation, and artificial evolution. Letter grading. Mr. Terzopoulos (W,Sp)

M276A. Pattern Recognition and Machine Learning. (4) (Same as Statistics M231.) Lecture, three hours. Designed for graduate students. Fundamental concepts and theories of 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, MLD, AIC), PCA/ICA/TCA, MDS, SVM, boosting, S/U or letter grading. Mr. Zhu

M276B. Structured Computation 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, four hours; outside study, eight hours. Requisite: course M276A or 276B. Design and analysis of system for communication in human/machine 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. Requisite: course 180D, Mathematica. Probabilistic models of human reasoning, perception, and other cognitive processes. Design and analysis of probabilistic models of human behavior in artificial intelligence systems. Introduction to conceptual foundations and basic math-
emotional and computational techniques. Topics illustrated on different aspects of cognition. S/U or letter grading.

279. Current Topics in Computer Science: Methodology. (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 as consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

280A-280ZZ. Algorithms. (4 to 6) 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 and general theory of algorithms; algorithms for particular application areas. Subtles of some current sections: Principles of Design and Analysis (280A); Distributed Algorithms (280D); Graphs and Networks (280G). 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. Basic algorithmic methods, discrete optimization problems. Theoretically sound techniques for dealing with NP-hard problems. Inability to solve these problems efficiently motivates algorithm designers on approximation—finding solution that is near to best possible in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include primal-dual methods, linear programming rounding, greedy algorithms, and local search. Letter grading.

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or 185, 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 of strings, and random access machines. Computation in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system modeling, and logic design. Mr. Ostrovsky (W).

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or 185, or compatible background. Computation in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system modeling, and logic design. Mr. Ostrovsky (W).

282A. 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, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public-key and private-key encryption, secret-sharing, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment perfectness, one-way functions and their generalizations, nondeterminism, decidability, unsolvable problems, “easy” and “hard” problems, PTIME/PP/NTIME. Letter grading.

283. Enzyme Kinetics. (4) Lecture, four hours; outside study, eight hours. Course 181. Models of computer programs and their simulation, algorithms for analyzing and optimizing computer programs, and two-party secure computation with statistical secrecy. Letter grading.

284A-284ZZ. Topics in Automata and Languages. (4 to 6) 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, grammars, machines, operators; pushdown automata, context-free languages and their grammars, parsing, multidimensional grammars, developmental systems; machine-based complexity. Subties of some current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284F). May be repeated for credit with consent of instructor and topic change. Letter grading.


289A-289ZZ. Current Topics in Computer Theory. (2 to 12 each) Lecture, four hours; outside study, eight hours. Requisite: course 289A. Current topics in the area of computer theory in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. Letter grading.

290A. Complexity Theory. (4) Lecture, four hours; outside study, eight hours. Diagonalization, polynomial-time hierarchy, PCP theorem, randomness and de-randomization, circuit complexity, attempts and limitations to proving P does not equal NP, average-case complexity, one-way functions, hardness amplification. Problem sets and presentation of previous and original research related to course topics. Letter grading.

290A. Complexity Theory. (4) Lecture, four hours; outside study, eight hours. Diagonalization, polynomial-time hierarchy, PCP theorem, randomness and de-randomization, circuit complexity, attempts and limitations to proving P does not equal NP, average-case complexity, one-way functions, hardness amplification. Problem sets and presentation of previous and original research related to course topics. Letter grading.

299A. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 289A. Introduction to decision making under uncertainty and competitive analysis. Review of current research in online algorithms for problems arising in many areas, such as data and memory management, searching and navigating in unknown terrains, and server systems. Letter grading.

299A. Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomized algorithms, such as probability theory, Markov chains, random walks, and probabilistic method. Applications to randomized algorithms in data structures, graph theory, computational geometry, number theory, and parallel and distributed systems. Letter grading.

M296A. Advanced Modeling Methodology for Dynamic Biological Systems. (4) (Same as Bioengineering M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmacological, chemical, and related systems. Control system, multicompartamental, noncompartmental, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other limited data environments. Problem solving in PC laboratory. Letter grading. Mr. DiStefano

M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Bioengineering M296B and Biostatistics M270, and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biostatistics 229. Estimation methodology and model parameter estimation algorithms for biomedical system models. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Same as Bioengineering M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biostatistics 229. Estimation methodology and model parameter estimation algorithms for biomedical system models. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano

M296D. Introduction to Computational Cardiology. (4) (Same as Bioengineering M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological processes. Topics include potential (AP), Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of
numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.

298. Research Seminar: Computer Science. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate computer science students. Discussion of advanced topics and current research in algorithmic processes that describe and transform information: theory, analysis, design, efficiency, implementation, and application. May be repeated for credit. 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. (F.W.Sp)

495. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, six hours. Limited to graduate Computer Science Department students. Seminar on communication of computer science materials in classroom: preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. Mr. Korf

597D-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 external company or organization that they investigate as candidate for possible computerization, submitting team report of their findings and recommendations. In Progress (497D) and S/U or letter (497E) grading. Mr. Cardenas

596. Directed Individual or Tutorial Studies. (1 to 8) 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.

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate computer science 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 computer science students. Preparation for Ph.D. preliminary examinations. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science 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 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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Asad M. Madni, Ph.D.
Ingrid M. Verbauwhede, Ph.D.
Eli Yablonovitch, Ph.D.

Adjunct Associate Professor
Keisuke Goda, 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 sys-
tems, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunication, 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.

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 program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. 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 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Electrical Engineering 101A, 101B, 102, 103, 110, 110L, 113, 115A, 115AL, 121B, 131A, 132A, 141, 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—Electrical Engineering 162A, 163A, 163C; one capstone design course from 164D or 184DA/184DB (count as one course); and one laboratory course—64L (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—115BL (or by petition from 194 or 199).

Microelectromechanical (MEMS) Systems: Three major field elective courses from Electrical Engineering 115B or 123A, 128 or 163A, and CM150; one capstone design course—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 170A, 170B, and 174 or M185; one capstone design course—173D; and one laboratory course—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—Electrical Engineering 123A, 123B, 128; one capstone design course—129D; and one laboratory course—22L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 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
The Major

**Required:** Electrical Engineering 101A, 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 CM186, 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 18 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 2, 3, 10, M16; Computer Science M51A; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

**The Major**

**Required:** Electrical Engineering 101A, 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 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—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 18 or http://www.registrar.ucla.edu/ge/.

**Graduate Study**

For information on graduate admission see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 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, 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 and minor fields of study according to the requirements listed below for the thesis (seven courses) and non-thesis (eight courses) options. The selected courses must be approved by the faculty adviser.

**Course Requirements**

Students may select either the thesis plan or the non-thesis (comprehensive examination) plan. The selection of courses 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.

The minimum requirements for the M.S. degree are as follows:

1. **Requisite.** B.S. degree in Electrical Engineering or a related field
2. All M.S. program requirements should be completed within two academic years from admission into the M.S. graduate program in the Henry Samueli School of Engineering and Applied Science
3. Students must maintain a minimum cumulative grade-point average of 3.0 every term and 3.0 in all graduate courses
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 of 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 221C, 260A, 260B, 261, 262, 263, 266, 270.


### 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 systems, 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.** Courses deal with digital signal processing theory, statistical signal processing, analysis and design of digital filters, digital speech processing, digital image processing, multi-

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 299) 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, microelectro-mechanical 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 into new electronic devices. Students, both graduate and undergraduate, 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 interdependent 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 (NCSCI), 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 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, ultrafast lasers, parametric frequency conversion, electro-optics, infra-
red 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-tun-
able dye lasers, as well as gallium arsenide,
heilum-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 spon-
sorship 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 cam-
era, and optical spectrographs and multi-
channel analyzer. Parametric instabilities
such as stimulated Raman scattering have
been studied, as well as the resonant exci-
tation 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
desorbed 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 sci-
ence. Dawson 2 consists of 96 HP L390
nodes each with 12 Intel X6650 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 linpack 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 facil-
ties include (1) a modern integrated semi-
conductor device processing laboratory, (2)
complete new Si and III-V compound molec-
ular beam epitaxy systems, (3) CAD and
mask-making facilities, (4) lasers for beam
crystalization study, (5) thin film and charac-
terization equipment, (6) deep-level transient
spectroscopy instruments, (7) computerized
capacitance-voltage and other characterization
equipment, including doping density
profiling systems, (8) low-temperature facil-
ties for material and device physics studies in
cryogenic temperatures, (9) optical equip-
ment, 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 hetero-
structures. The laboratory facilities are avail-
able 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 Architecton-
 ics 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-
tories that cover a wide spectrum of speciali-
ties, including
• Actuated Sensing and Coordinated
  Embedded Networked Technologies
  (ASCENT) Laboratory (Kaiser)
• 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
  (Roychowdhury)
• Complex Networks Group
  (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 (Diggiavi)
• Integrated Circuits and Systems
  Laboratory (Abidi)
• Laser-Plasma Group (Joshi)
• Microwave Electronics Laboratory (Itoh)
• Millimeter Wave and Optoelectronics
  Laboratory (Petterman)
• Nanoelectronics Research Center
  (Candler, Franz)
• Nanostructure Devices and Technology
  Laboratory (Chui)
• Nanosystems Computer-Aided Design
  Laboratory (Gupta)
• Networked and Embedded Systems Lab-
  oratory (Srivastava)
• Optoelectronics Circuits and Systems
  Laboratory (Jalali)
• Optoelectronics Group (Yablonovitch)
• Proactive Mediante Laboratory
  (van der Schaar)
• Public Safety Network Systems
  Laboratory (Yao, Rubin)
• Quantum Electronics Laboratory
  (Stafsudd)
• Sensors and Technology Laboratory
  (Candler)
• Speech Processing and Auditory Percep-
  tion 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

Abeer A.H. 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 Ariki, Ph.D. (U. Tokyo, Japan, 1985)
High-energy and astro-particle experiments

M.-C. Frank Chang, Ph.D. (National Chiao-Tung, Taiwan, 1979)
High-speed semiconductor (GaAs, InP and Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications

Panagiota D. Christofides, Ph.D. (Minnesota, 1990)
Process modeling, dynamics and control, computational and applied mathematics

Jing-Sheng Jason 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

Suhas Digavi, 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 modeling and design, power-efficient computer architectures and systems, numerical and combinatorial optimization

Diana L. Huffaker, Ph.D. (Texas, Austin, 1995)
Solid-state nanotechnology, MMWR optoelectronic devices, solar cells, Si photonics, novel materials

Tatsuo Ishi, 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 metasurfaces 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, nonlinear optics, high-power lasers, plasma physics

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. (Minn, 1974)
Numerical linear algebra, numerical analysis, condition estimation, computer-aided control system design, high-performance computing

Kuo-Nan Liu, 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, ultrastable optics, laser chaos, semiconductor lasers, optoelectronics, photonic, nonlinear and ultrafast processes

Warren B. Mori, Ph.D. (UCLA, 1987)
Laser and charged particle beam-plasma interaction, 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, quantum 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

Ya’ham Rahmat-Samii, Ph.D. (Illinois, 1975)
Satellite communications antennas, personal communication antennas including human interactions, antennas for remote sensing and radio astronomy applications, advanced numerical and geometric techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory

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/D and D/A converters, high-speed data communication circuits

Wanli Roy Chowdhury, Ph.D. (Stanford, 1989)
Models of computing and distributed processing systems, quantum computation and information processing, circuits and computing paradigms for nano-electronics and molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory

Izhak Rubin, Ph.D. (Princeton, 1970)
Telecommunications and computer communications systems and networks, mobile wireless networks, multimedia IP networks, UAW/GIG-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering

Henry Samueli, Ph.D. (UCLA, 1980)
VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design

Ali H. Sayed, Ph.D. (Stanford, 1992)
Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems

Stefano Soatto, Ph.D. (Caltech, 1996)
Computer vision, systems and control theory, detection and estimation, robotics, system identification, shape analysis, motion analysis, image processing, video processing, autonomous systems

Jason L. Speyer, Ph.D. (Harvard, 1968)
Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

Omar M. Stafsudd, Ph.D. (UCLA, 1967)
Quantum electronics: I.R. lasers and nonlinear optics; solid-state: I.R. detectors

Paulo Tabuada, Ph.D. (Technical U. Lisbon, Portugal, 2002)
Real-time, networked, embedded control systems; mathematical systems theory including discrete-event, timed, and hybrid systems; geometric nonlinear control; algebraic/algorithmic methods

Kung-Nei Tu, Ph.D. (Harvard, 1968)
Kinetic processes in thin films, metal-silicon interfaces, electromigration, Pb-free interconnects

Lieve Vandenberghe, Ph.D. (Katholieke U., Leuven, Belgium, 1990)
Optimization in engineering and applications in systems and control, circuit design, and signal processing

Michael van der Schaar, Ph.D. (Eindhoven U. of Technology, Netherlands, 2001)
Multimedia processing and compression, multimedia networking, multimedia communications, multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing

John D. Villasenor, Ph.D. (Stanford, 1989)
Communications, signal and image processing, configurable computing systems, and design environments

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoelectronics and optoelectronics, nano and molecular devices, MBE and superlattices, microwave and millimeter electronics, quantum information

Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and 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. Ken Yang, Ph.D. (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design

Kung Yao, Ph.D. (Princeton, 1965)
Communication theory and signal 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

F. W. Balakrishnan, Ph.D. (USC, 1954)
Control and communications, flight systems applications

Francis C. Chen, Ph.D. (Harvard, 1964)
Radio frequency plasma sources and diagnostics for semiconductor processing

* Also Professor of Physics
† Also Professor Emeritus of Mathematics
Harold R. Fettermann, 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*

Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)  
*Operations research, mathematical programming, combinatorial optimization, applications of mathematical programming to engineering and 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, applied electromagnetics*

Gabor C. Temes, Ph.D. (Ottawa, 1961)  
*Analysis and design of MOS integrated circuits, signal processing, analog and digital filters*

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*

*Control systems, modeling and control of non-linear distributed-parameter systems with applications to micro-optoelectromechanical systems, micro and nano manipulation systems, coordination and control of multiple microspacecraft in formation*

Donald M. Wiberg, Ph.D. (Caltech, 1965)  
*Nanoelectronic and optoelectronic devices and technology, heterostructure semiconductor devices, monolithic integration of hetero-necus technology, exploratory nanotechnology*

Christina Fragiouli, Ph.D. (UCLA, 2000)  
*Network information flow theory and algorithms network coding, connections between communications and computer science*

Puneet Gupta, Ph.D. (UC San Diego, 2007)  
*CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing*

Mark H. Hansen, Ph.D. (UC Berkeley, 1994)  
*Estimation and inference, statistical learning, data analysis, model selection, nonparametric methods; visualization and information design*

Mona Jarrahi, Ph.D. (Stanford, 2007)  
*Radar front-end, microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonics and optoelectronics*

Dejan Parkovic, Ph.D. (UC Berkeley, 2000)  
*Power-area-efficient digital integrated circuits, VLSI architectures for wireless communications, organization methods and supporting CAD flows*

Aydogan Ozcan, Ph.D. (Stanford, 2005)  
*Biophotonics, nano-photronics, nonlinear optics, optical microscopy, plasmonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication*

Yuanwen Ethan Wang, Ph.D. (Texas, Austin, 1999)  
*Smart antennas, RF and microwave power amplifiers, numerical techniques, DSP techniques for microwave systems, phased arrays, wireless and radar systems, microwave integrated circuits*

Benjamin Williams, Ph.D. (MIT, 2003)  
*Development of terahertz quantum cascade lasers*

Assistant Professors  

Daniela Cabric, Ph.D. (UC Berkeley, 2007)  
*Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and digital communication algorithms, performance analysis and experiments on embedded system platforms*

Robert N. Candler, Ph.D. (Stanford, 2006)  
*MEMS and nanoscale devices, fundamental limitations of sensors, packaging, biological and chemical sensors, self-assembly and self-replication strategies; alternate image acquisition, reconstruction, and processing techniques*

Lara Dolecek, Ph.D. (UC Berkeley, 2007)  
*Information and coding theory; graphical models, statistical algorithms and computational methods with applications to large-scale and complex systems for data processing, communication and storage*

Florian Dörfler, Ph.D. (UC Santa Barbara, 2013)  
*Synchronization in complex oscillator networks and power grids; control, monitoring, and security in cyber-physical systems and smart power grids; cooperative control and coordination in autonomous multi-agent systems*

Adjunct Professors  

Enzo Biglietti, Dr. Ing. (Politecnico di Torino, Italy, 1967)  
*Digital communication, wireless channels, modulation, error-control coding, signal processing in telecommunications*

Dariush Divsalar, Ph.D. (UCLA, 1978)  
*Information theory, communication theory, bandwidth-efficient combined coding modulation techniques, spread spectrum systems and mutual user interference cancellation for CDMA, turbo codes, binary and nonbinary LDPC codes, iterative decoding*

Mary Estghalian-Wilner, Ph.D. (USC, 1998)  
*Nanoscale architectures, bioinformatics networked networks, heterogeneous computing, mapping and scheduling paradigms, optical interconnects, VLSI and reconfigurable chips, parallel algorithms for image processing*

Joel Schulman, Ph.D. (Caltech, 1979)  
*Semiconductor super lattices, solid-state physics*

Maria Eshagian-Wilner, 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, plasmonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication*

Adjunct Associate Professor  

Keisuke Goda, Ph.D. (MIT, 2007)  
*Biophotonics, imaging, fiber-optic communications*

Adjunct Assistant Professor  

Jin Hyung Lee, Ph.D. (Stanford, 2004)  
*Advanced imaging techniques for biomedical applications; neuromorphic systems; magnetic resonance imaging (MRI); development of novel image contrast strategies; alternate image acquisition, reconstruction, and processing techniques*

Lower Division Courses  

2. Physics for Electrical Engineers. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Requisite: Physics 1C. Introduction to concepts of modern physics necessary to understand solid-state devices, including elementary quantum theory, Fermi energies, electrons in solids. Discussion of electrical properties of semiconductors leading to operation of junction devices. Letter grading.  

3. Introduction to Electrical Engineering. (3) Lecture, two hours; laboratories, two hours; outside study, five hours. Requisite: Physics 1B. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunications, electrical grid, automatic computing and control, and enabling device technology. Researchfrontiers of electrical engineering. Introduction to measurement and design of electrical circuits. Letter grading.  

M. Pottie, Mr. Stafusick (F,W)


Mr. Gupta, Mr. Razavi (F,W)

M16. Logic Design of Digital Systems. (4) (Same as Computer Science M16A) Lecture, four hours; discussion; two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standards, design methods, 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. Gupta, Mr. Srivasvatha (F,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, four hours; discussion; four hours; outside study, four hours. Requisites: Mathematics 33A, 33B, Physics 1C. 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.  

Mr. Razavi (F,W)

101A. Electromagnetic Engineering. (4) Lecture, four hours; discussion; one hour; outside study, seven hours. Requisites: Mathematics 32A and 32B, or 33A and 33B, Physics 1C. Electromagnetic fields, conducting media, waves and phasors, transmission lines and Smith chart, transient re-
spones, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading. (3)

Mr. Joshi, Mr. Williams (FW)

101B. Electromagnetic Waves. (4) (Formerly numbered 161.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 10A. Time-varying fields and systems, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radi- ation and antennas. Letter grading. (4)

Mr. Y.E. Wang (W,Sp)

102. Systems and Signals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Mathematics 33A. Corequisite: Mathematics 33B. Elements of differential equations, first- and second-order equations, variation of parameters. Letter grading. (4)

Ms. Cabric, Ms. Fragouli (F,Sp)

103. Applied Numerical Computing. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Requisites: Civil Engineering 15 or Computer Science 31, Mathematics 33A, 33B (33B may be taken concurrently). Introduction to numerical computing and analysis. Floating point representation and round-off error; numerical methods for systems of linear equations; methods for systems of nonlinear equations. Introduction to numerical optimization, linear programming, least squares, interpolation, numerical integration; and differential equations. Letter grading. (4)

Mr. Dolecek, Mr. Vandenberghe (F,Sp)

110. Circuit Analysis II. (4) Lecture, three hours; dis- cussion, one hour; laboratory, two hours. Requi- site: course 10. Corequisite: course 102. Sinusoidal steady state, power network functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis. Letter grading. (4)

Ms. Dzhanidze, Mr. Sayed (F,Sp)

110L. Circuit Measurements Laboratory. (2) Labo- ratory, four hours; outside study, two hours. Requi- site: course 100 or 110. Experiments with basic cir- cuits containing resistors, capacitors, inductors, and op-amps. Ohm's law voltage and current division. Thevenin and Norton equivalents, transient circuits, superposition, transient and steady state analysis, and frequency response principles. Letter grading. (2)

Mr. Razavi (FW,Sp)


Mr. Daneshdar, Mr. Sayed (F,Sp)

113D. Digital Signal Processing Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 113. Design techniques for signal processing systems. Speech recognition, audio, and video using DSP chip. Letter grading. (4)

Mr. Briggs (FSp)

114. Speech and Image Processing Systems De- sign, (4) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. En- forced requisite: course 113. Design techniques for speech and image processing systems. Speech proc- eduction, 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. (4)

Mr. Villasenor (W)

115A. Analog Electronic Circuits I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Analysis and design of small-signal circuits using bipolar and CM technology. Letter grading. (4)

Mr. Razavi (W,Sp)

115AL. Analog Electronics Laboratory I. (2) Labo- ratory, four hours; outside study, two hours. Enforced requisite: courses 110L, 115A. Experimental deter- mination of device characteristics, resistive diode cir- cuits, single-stage amplifiers, compound transistor stages, effect of feedback on single-stage amplifiers, operational amplifiers, and operational amplifier cir- cuits. Introduction to hands-on design experience based on individual student hardware design and imple- mentation platforms. Letter grading. (2)

Mr. Villasenor (W)

115B. Analog Electronic Circuits II. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 115A. Analysis and design of circuits using bipolar and MOS technologies. Current mirrors and active loads. Fre- quency response of amplifiers. Feedback and its properties. Stability issues and frequency compensa- tion. Letter grading. (4)

Mr. Razavi (W)

115CL. Analog Electronics Laboratory II. (2) Labo- ratory, four hours; outside study, eight hours. En- forced requisite: course 115B. Recommended corequi- site: course 115D. Study of high-frequency effects in discrete circuit design. Laboratory experiments in- clude transmission lines, tuned amplifiers, oscillators, mixers, and broadband amplifiers. Hands-on experi- ence in construction of surface-mount circuits and their characterization. Letter grading. (2)

Ms. Cabric, Mr. Yang (W,Sp)

115C. Digital Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Computer Science M51A. Recommended: course 115B. Tran- sistor-level digital circuit analysis and design. Modern logic families (static CMOS, pass-transistor, dynamic logic), integrated circuit (IC) layout, digital circuits (logic gates, flipflops, PLA’s, D/A converters, etc.), computer-aided simulation of digital circuits. Letter grading. (4)

Ms. Cabric, Mr. Yang (W,Sp)


Mr. Abdii (FW,Sp)

M116C. Computer Systems Architecture. (4) (Same as Computer Science M151B.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M16 or Computer Science M51A. Computer Science 33. Recommend- ed: course M116L or Computer Science M152A; Computer Science 111. Computer system organiza- tion and architecture. Computer instruction set; memory and I/O interfaces, datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupt controllers, DMA), performance evaluation, pipelined processors. Letter grading. (4)

Mr. Gupta (W,Sp)

M116L. Introductory Digital Design Laboratory. (2) (Same as Computer Science M152A.) Laboratory, four hours. Enforced requisite: course M152A. Recommended corequi- site: course M16 or Computer Science M51A. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, imple- mentation of complex circuits using programmed ar- ray logic, design projects. Letter grading. (2)

Mr. He (FW,Sp)

M117. Computer Networks: Physical Layer. (4) (Same as Computer Science M117.) Lecture, two hours; discussion, one hour; outside study, six hours. Enforced requisite: course M117L. Introduction to fundamental computer communication concepts underlying and supporting modern networks, with focus on wireless communications and media access layers of network protocol stack. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks. Letter grading. (4)

Mr. Dzhanidze (W,Sp)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: courses 2, 121B may be taken concurrently. Series of experiments conducted to enable students to gain a better understanding of semiconductor transport properties and semiconductor device characteristics to see interplay between various device performance metrics. Letter grading. (4)

Mr. Dzhanidze (W,Sp)

121L. Semiconductor Device Design Laboratory. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 2, 121B may be taken concurrently. Design and characterization of p-n junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metatilization, and photolithography. Letter grading. (4)

Mr. Candler (W)

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 2 or Physics 1C. Limiting behavior and performance of solid-state devices such as analysis of dynamics, variability, and noise of modern MOS transistors. Applications to solid-state, introduction to quantum mechanics and quantum statistics applied to solid-state. Crystal structure, energy levels in solids, and band theory and semiconductor properties. Letter grading. (4)

Ms. Huffaker (F)

123B. Fundamentals of Solid-State II. (4) Lecture, three hours; outside study, nine hours. Enforced requi- sites: course 123A. Discussion of solid-state proper- ties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading. (4)

Ms. Huffaker (W)

128. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Enforced requisite: Physics 1C. Introduction to funda- mentals of nanotechnology for electronics engineering. Principles of fundamental quantities: electron charge, effective mass, Boltzmann, and spin, as well as theoretical approaches. From these nanoscale com- ponents, discussion of basic behaviors of nanosys- tems such as analysis of dynamics, variability, and noise, contrasted with those of scaled CMOS. Incorpora- tion of design project in which students are chal- lenged to design electronics nanosystems. Letter grading. (4)

Mr. K.L. Wang (Sp)

129D. Semiconductor Processing and Device De- sign. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 121B. Introduction to CAD tools used in integrated circuit processing and device design. Device struc- ture determination tool and circuit layout tool. Process integration tool is based on SUPREM. Course famil-
aryzes students with those tools. Using CAD tools, CMOS process integration to be designed. Letter grading.

131A. Probability. (4) Lecture, four hours; discussion, one hour; outside study, ten hours. Requisites: course 102, Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables, discrete and continuous distributions, 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. Yao (FW)

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. Introduction to computer simulation and analysis of stochastic processes. Letter grading. Mr. Balakrishnan (Not offered 2013-14)


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 analysis and design. Multiple-access communications: TDMA, FDMA, polling, random access. Local, metropolitan, wide area, integrated services networks. Letter grading. Mr. Rubin (F)


142. Linear Systems: State-Space Approach. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 102. State-space methods of linear system analysis and synthesis, with application to problems in networks, control, and system modeling. Letter grading. Mr. Levan, Mr. Tabuada (WSp)

CM150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Bioengineering CM150 and Mechanical and Aerospace Engineering CM180) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methodology 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 CM250A. Letter grading. Mr. Liu (M)

150DL. Photonic Sensor Design Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, eight hours. Enforced requisite: course CM150. Design and implementation of optical gyroscopes, computer interfacing, and signal processing. Letter grading. (Not offered 2013-14)

CM150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM150L and Mechanical and Aerospace Engineering CM180L) Lecture, one hour; laboratory, four hours; outside study, seven hours. Requisite: course CM150, Chemistry 20A, 20L, Physics 1A, 1B, 1C. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Design and implementation of optical gyroscopes, computer interfacing, and signal processing. Letter grading.

152A. Wireless Communication Links and Antennas. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 161. Basic principles of transmitting and receiving antennas and antenna arrays. Array synthesis. Adaptive arrays. Friis transmission formula, radar equations. Cell-site and mobile antennas, bandwidth budget. Noise in microstrip 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-Sani (L)

163A. Introductory Microwave Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Transmission line discontinuities, impedance matching techniques, power dividers, directional couplers, active devices, transistor amplifier design. Letter grading. Mr. Y.E. Wang (F)

163C. Introduction to Microwave Systems. (4) Lecture, three hours; discussion, one hour; outside study, six hours. Enforced requisite: course 101B. Microwave integrated circuit design from the perspective of power switching, with focus on the use of microwave circuit simulation tools, design of microwave integrated circuits, microwave components, measurement techniques, and applications. Introduction to microwave integrated circuit design and implementation. Letter grading. Mr. Chang (Sp)

164A. Microwave Microwave Design. (4) Lecture, one hour; laboratory, four hours; outside study, seven hours. Enforced requisite: course 101B. Microwave integrated circuit design from the perspective of power switching, with focus on the use of microwave circuit simulation tools, design of microwave integrated circuits, microwave components, measurement techniques, and applications. Introduction to microwave integrated circuit design and implementation. Letter grading. Mr. Y.E. Wang (W)

164D. Microwave Microwave Design. (4) Lecture, one hour; laboratory, four hours; outside study, seven hours. Enforced requisite: course 101B. Microwave integrated circuit design from the perspective of power switching, with focus on the use of microwave circuit simulation tools, design of microwave integrated circuits, microwave components, measurement techniques, and applications. Introduction to microwave integrated circuit design and implementation. Letter grading. Mr. Y.E. Wang (W)

170A. Principles of Photonics. (4) Lecture, four hours; recitation, one hour; laboratory, four hours. Enforced requisite: courses 2, 101A. Development of solid foundation on essential principles of photonics from ground up with minimum prior knowledge on this subject. Topics include optical properties of materials, optical interferometers and resonators, optical coupling and modulation, optical absorption and emission, properties of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (F)

170B. Photonic Devices and Circuits. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 170A. Fundamentals of detection of light for communication and sensing, as well as conversion of light to electrical energy in solar cells. Introduction to radiometry, semiconductor photodetectors, noise processes and figures of merit, thermocouples, photodiodes, and the study of various types and materials. Letter grading. Mr. Liu (Sp)

170L. Laser and Light-Emitting Diodes. (4) (Formerly numbered 172L) Laboratory, four hours; outside study, eight hours. Enforced requisite: course 101B. Properties of lasers, including saturation, gain, mode structure, Laser applications, including optics, modulation, communication, holography, and interferometry. Letter grading. Mr. Stafsudd (F)

M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Computer Science M171L Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: course M116L. Limited to seniors. Not open to students with credit for course M117. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations for experiments on digital transmission, error detection, and transmitters, including LEDs and other photonic devices. Letter grading. Mr. Dzhianidze (WSp)

173D. Photonics and Communication Design. (4) Lecture, one hour; laboratory, four hours; outside study, eight hours. Enforced requisite: course 101B. Recommended: course 132A. Introduction to measurement of basic photonic devices, including LEDs, laser diodes, photodetectors, and interference-based transducers, polarimeters, multiplexing and sensor networks, physical and biomedical sensor systems. Design and implementation of optical gyroscopes, computer interfacing, and signal processing. Letter grading.

174. Semiconductor Optoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 170A. Introduction to semiconductor optoelectronic devices for optical communications, interconnects, and signal processing. Basic optical properties of semiconductors, p-n junctions, lasers, transistors, and current to voltage conversion (APD), light-emitting diodes (LED), semiconductor lasers, optical modulators and amplifiers, and optical communication systems. Letter grading. (Not offered 2013-14)

176. Photons in Biomedical Applications. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101. Study of different types of optical systems and their applications in the biomedical and biotechnological fields. Emphasis on current and projected biomedical applications. Specific capabilities of photonics to be related to each example. Lecture grading. Mr. Ozcan (Sp)

180D. Systems Design. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Recommended preparation: senior Electrical Engineering majors. Advanced systems design integrating communications, control,
and signal processing subsystems. Different project to be assigned yearly in which student teams create high-performance designs that manage trade-offs among subsystems. Letter grading.

Mr. Kaiser, Mr. Pottie (FW)

181D. Robotic Systems Design. (4) Lecture, four hours; laboratory, four hours; outside study, six hours. Requisites: course M116, M110L, M111L, Computer Science M152A, Computer Science 31, 33. Recommended: courses 113, 141, Computer Science 35L. Design of robotics systems that combine embedded control, software, mechanical systems, and fundamental algorithms for sensing and control to expose students to basic concepts in robotics and current state of art. Lecture closely tied to laboratory where students work in teams to construct series of subsystems leading to final projec- letter grading. (Not offered 2013-14)

184DA-184DB. Independent Group Project Design. (2-2) Formerly numbered 184D.) Laboratory, five hours; outside study, eight hours; one period per week. Students work as teams under faculty mentor. Culminating paper for seniors. Supervised individual research or investigation and system platforms such as field programmable circuits and systems, including introduction to circuit design and specification of system behavior, software or- ganization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery system design, timing synchronization, fault tolerance and debug- ging, and techniques for hardware and software ar- chitecture optimization. Theoretical foundations as well as practical design methods. Letter grading.

Mr. Pratavast (W)

M202A. Embedded Systems. (4) (Same as Comput- er Science M213A) Lecture, four hours; outside study, eight hours. Designed for junior/senior computer science and electrical engineering students. Method- ologies and technologies for design of embedded systems. Topics include hardware and software plat- forms for embedded systems, techniques for modeling of software and hardware, debugging, testing, and specification of system behavior, software or- ganization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery system design, timing synchronization, fault tolerance and debug- ging, and techniques for hardware and software ar- chitecture optimization. Theoretical foundations as well as practical design methods. Letter grading.

Mr. Gupta (F)

M202B. Energy-Aware Computing and Cyber- Physical Systems. (4) (Same as Computer Science M213B.) Lecture, four hours; outside study, eight hours. Requisite: course M16 or Computer Science M51A. Recommended: course M116C or Computer Science M151B, and Computer Science 111. Sys- tem-level management and cross-layer methods for power and energy consumption in computing and communication at various scales ranging across em- bedded, mobile, personal, enterprise, and data-cen- ter scale. Computing, networking, sensing, and con- trol technologies for improving energy sustainability in human-physical systems. Top- ics include modeling of energy consumption, energy sources, and energy storage; dynamic power man- agement; power-aware computing and energy proportionality; duty-cycling; power-aware schedul- ing; low-power protocols; battery modeling and man- agement; thermal management; sensing of power consumption. Lecturers: Dr. Raviv Swart (Sp), Mr. Briggs (FW) M185. Introduction to Plasma Electronics. (4) (Same as Physics M122.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requi- site: course 101A or Physics 110A. Senior-level intro- ductionary course on electrodynamics of ionized gases and applications to materials processing, generation of coherent light and plasma sources, and related re- active energy sources. Letter grading.

Mr. Mori (F)

188. Special Courses in Electrical Engineering. (4) Seminar, four hours; outside study, eight hours. Spe- cial topics in electrical engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Offered 2013-14)

194. Research Group Seminars: Electrical Engi- neering. (2 to 4) Seminar, four hours; outside study, eight hours. Students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Not offered 2013-14)

Graduate Courses

201A. VLSI Design Automation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 115C. Fundamentals of design automation of VLSI circuits and systems, including introduction to circuit and system platforms such as field programmable gate arrays and multi-core systems; high-level synthe- sis, logic synthesis, and technology mapping; physical design; and testing and verification. Letter grading.

Mr. Hwang (F)


Mr. He (W)

M202A. Embedded Systems. (4) (Same as Comput- er Science M213A) Lecture, four hours; outside study, eight hours. Designed for junior/senior computer science and electrical engineering students. Method- ologies and technologies for design of embedded systems. Topics include hardware and software plat- forms for embedded systems, techniques for model- ing of software and hardware, debugging, testing, and specification of system behavior, software or- ganization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery system design, timing synchronization, fault tolerance and debug- ging, and techniques for hardware and software ar- chitecture optimization. Theoretical foundations as well as practical design methods. Letter grading.

Mr. Kaiser (F)


Mr. Laub (FW)

205B. Functional Analysis for Applied Mathe- matics and Engineering. (4) (Same as Mathema- tics 206B.) Lecture, four hours; outside study, eight hours. Pre-requisites: course M206A (or Mathematics 115A and 115B), Mathematics 131A, 131B, 132. Top- ics may include L_p[s] spaces, Hilbert, Banach, and separable spaces; Fourier transforms; linear function- als, Riesz representation theory, linear operators and their adjoints; self-adjoint and compact operators. Spectral theory. Differential operators such as Lapla- cian and eigenvalue problems. Resolvent distribu- tions. Green’s functions. Partial differential equa- tions. SU or letter grading. (Not offered 2013-14)

M208B. Special Topics in Circuits and Embedded Systems. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of cir- cuits and embedded systems, such as digital, ana- log, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; embedded processor architectures; embedded software; distribut- ed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. SU or letter grading.

Mr. Gupta, Mr. He (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; or arbitrary filter banks; wavelet transforms and its relation to multirate filter banks. Letter grading. Mr. Wilson (Not offered 2013-14)

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 2013-14)


214B. Advanced Topics in Speech Processing. (4) Lecture, three hours; computer assignments, two hours; outside study, seven hours. Requisite: course M214A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and machine. Physiology and psychoacoustics of human perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired. Letter grading. Ms. Alwan (Sp)

215A. Analog Integrated Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115B. Analysis and design of analog integrated circuits. MOS and bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and discrete-time circuits, bandgap reference. Letter grading. Mr. Abidi (F)

215B. Advanced Digital Integrated Circuits. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 115C, M216A. Analysis and comparison of basic circuit blocks, CAD tools and cell libraries for application specific integrated circuit design; case studies of speech and image processing circuits. Letter grading. Mr. Markovic (F)

M216A. Digital Circuit and System Design. (4) (Same as Computer Science M216A) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisites: courses M16 or M51B, and course M115B. Recommended: course 115G. Design and implementation of digital systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading. Mr. Markovic (Sp)

216B. VLSI Signal Processing. (4) Lecture, four hours; outside study, eight hours. Advanced concepts in VLSI signal processing, with emphasis on architectural design. Letter grading. Mr. Markovic (F)

M217. Biomedical Imaging. (4) (Same as Bioengineering M217) Lecture, three hours; outside study, nine hours. Requisite: course 114 or 211A. Optical imaging modalities and biomedical imaging. Other nonoptical imaging modalities discussed briefly for comparison purposes. Letter grading. Mr. Ozcan (W)

218. Network Economics and Game Theory. (4) Lecture, four hours; outside study, eight hours. Discussion of how different cooperative and noncooperative games among agents can be constructed to model, analyze, optimize, and shape emerging interactions among users in different networks and system settings. How strategic agents can successfully compete with each other for limited and time-varying resources by optimizing their decision process and learning from their past interaction with other agents. To determine their optimal actions in these distributed, informationally decentralized environments, agents need to learn and model directly or implicitly other agents' responses to their actions. Discussion in detail several game theory techniques that can be successfully deployed in multiagent systems. Letter grading. Ms. van der Schaar (W)

221A. Physics of Semiconductor Devices I. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of junction devices. Letter grading. Mr. Wei (F)

221B. Physics of Semiconductor Devices II. (4) Lecture, four hours; outside study, eight hours. Principles and design considerations of field effect devices and charge-coupled devices. Letter grading. Mr. Wei (W)

221C. Microwave Semiconductor Devices. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of micro wave solid-state devices: Schottky barrier mixer diodes, IMPATT diodes, transferred electron devices, tunnel diodes, microwave transistors. Letter grading. Mr. Chang (Sp)

222. Integrated Circuits Fabrication Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 2. Principles of integrated circuits fabrication processes and limitations of integrated circuits design. Topics include bulk crystal and epitaxial growth, thermal oxidation, diffusion, ion-implantation, chemical vapor deposition, dry etching, backside metalization. Introduction of advanced process simulation tools. Letter grading. Mr. Chiu (F)

223. Solid-State Electronics I. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 12A, 270. Energy band theory, electronic band structure of various elementary, compound, and alloy semiconductors, defects in semiconductors. Recombination mechanisms, transport properties. Letter grading. Mr. Chui (F)

225. Physics of Semiconductor Nanostructures and Devices. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods for determining physical properties of semiconductor structures. Quantum size effects and low-dimensional systems. Application to semiconductor nanometer scale devices, including negative resistance diodes, transistors, and detectors. Letter grading. Ms. Hufkett (Sp, alternate years)

229. Seminar: Advanced Topics in Solid-State Electronics. (4) Seminar, four hours; outside study, eight hours. Requisites: courses 223, 224. Current research areas, such as radiation effects in semiconductor devices, diffusion in semiconductors, optical and microwave semiconductor devices, nonlinear optics, and electron emission. Letter grading. (Not offered 2013-14)

229S. Advanced Electrical Engineering Seminar. (2) Seminar, two hours; outside study, six hours. Preparation: successful completion of Ph.D. major field examination. Seminar on current research topics in solid-state devices and circuits and operation in electronic circuit theory and applications (Section 1). Students report on tutorial topic and on research topic selected from dissertation area. Letter or credit. S/U grading. (Not offered 2013-14)

230A. Estimation and Detection in Communication and Radar Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Principles of estimation and detection concepts in communication and radar engineering; random signal and noise characterization by analytical and simulation methods; mean square (MS) and maximum likelihood (ML) estimation and detection algorithms; detection under ML, Bayes, and Neyman-Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Letter grading. Mr. Yao (F)

230B. Digital Communication Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 132A, 230A. Basics of digital communication systems; representation of bandpass waveforms; signal space analysis and optimum receivers in Gaussian noise; comparison of digital modulation methods; synchronization and adaptive equalization; applications to modern communication systems. Letter grading. S/U grading. Mr. Seturi (W)


230D. Signal Processing in Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230C. Basic digital signal processing techniques for estimation and detection of signals in communication and radar systems. Optimization of dynamic range, quantization, and state constraints; DFT, convolution, FFT, NTT, Winograd DFT, systolic array; spectral analysis-windowing, AR, and ARMA; system applications. Letter grading. Mr. Yao (Sp)

231A. Information Theory: Channel and Source Coding. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Fundamental limits on compression and transmission of information. Topics include limits and algorithms for lossless data compression, channel capacity, rate distortion theory, and information theory for multiple users. Letter grading. Ms. Dolecek (W)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Fundamentals of error control codes and de-
coding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading. (Not offered 2013–14)

232A. Stochastic Modeling with Applications to Telecommunication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Introduction to stochastic processes to study of telecommunications systems and traffic engineering. Renewal theory; discrete-time Markov chains; continuous-time Markov jump processes. Applications to traffic and queueing analysis of basic telecommunication system models. Letter grading. (Not offered 2013–14)

232B. Telecommunication Switching and Queuing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232A. Queue modeling and analysis with applications to space-time digital switching systems and to integrated-service telecommunication systems. Fundamentals of traffic engineering and queuing theory. Queue size, waiting time, busy period, blocking, and stochastic process analysis for Markovian and non-Markovian models. Letter grading. Mr. Rubin (W)


232D. Telecommunication Networks and Multiple-Access Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Performance analysis and design of telecommunication networks and multiple-access communication systems. Topics include architectures, multiplexing and multiple-access, message delays, error/flow control, admission control, and applications to local-area, packet-radio, local-distribution, computer and satellite communication networks. Letter grading. Mr. Rubn (Sp)

232E. Graphs and Network Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230B. Analysis and design of telecommunications and computer networks. Topics include graph-theoretic methods; application to communication, transportation, and transmission problems. Letter grading. Mr. Roychowdhury (Sp)

233, Wireless Communication Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230B. Various aspects of physical layer and medium access 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 nonideal components, hardware partitioning issues. Case study highlights system level trade-offs. Letter grading. Mr. Pottie (Sp)

234A. Linear Programming. (4) Lecture, four hours; outside study, eight hours. Requisite: Mathematics 115A or equivalent knowledge of linear algebra. Basic graduate course in linear optimization. Geometry of linear programming. Duality, Simplex method, Interior-point methods. Decomposition and large-scale linear programming, quadratic programming and complementary pivot theory. Engineering applications. Introduction to integer linear programming and computational complexity theory. Letter grading. Mr. Vanderbei (F)


237. Dynamic Programming. (4) Same as Mechanical and Aerospace Engineering M276G. Lecture, four hours; outside study, eight hours. Recommend: requisite course 232A or 236A or 236B. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. (Not offered 2013–14)

238. Multimedia Communications and Processing. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131A. Key concepts, principles, and algorithms of real-time multimedia communications and processing across heterogeneous Internet and wireless channels. Due to flexible, low-cost infrastructure, new networks and communication channels enable variety of delay-sensitive multimedia applications and provide varying resources with limited support for quality of service required by delay-sensitive, bandwidth-intensive, and loss-tolerant multimedia applications. New theoretical 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 2013–14)

239A. Special Topics in Signals and Systems. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of signals and systems, such as control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U or letter grading. Mr. Diggavi, Ms. Dolecek, Ms. Fragouli, Mr. Roychowdhury (W, 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, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U grading. (Not offered 2013–14)

240A. Linear Dynamic Systems. (4) Same as Chemical Engineering M280A and Mechanical and Aerospace Engineering M272A.) Lecture, four hours; outside study, eight hours. Requisite: course 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 eigenvalues and eigenvectors, 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. Mr. Tabuada (F)

240B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 141, Mechanical and Aerospace Engineering 235LA. Linear quadratic Gaussian control and related topics. Introduction to detailed study of LQR, or linear regulators with quadratic cost criteria. Relationships to classical control system design. Letter grading. (Not offered 2013–14)

M240C. Optimal Control. (4) (Same as Chemical Engineering M280C and Mechanical and Aerospace Engineering M272C.) Lecture, four hours; outside study, eight hours. Requisite: course 240B. Applications for global cost optimization: Pontryagin maximum principle, Hamilton/Jacobi Bellman equation (dynamical programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. (Not offered 2013–14)


241C. Stochastic Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 240B, 241B. Linear quadratic Gaussian theory of optimal feedback control of stochastic, time-invariant state-space models: sigma algebra equivalence and separation principle; dynamic programming; compensator design for time invariant systems; feedforward control and servomechanisms, extensions to nonlinear systems. Applications to queuing, communication, and control. Letter grading.


243. Robust and Optimal Control by Convex Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: course M240A. Multivariable robust control by convex methods and robust performance analysis and synthesis against structured uncertainty. Emphasis on convex methods for analysis and design, in particular linear matrix inequality (LMI) approach to control synthesis. Letter grading. (Not offered 2013–14)

M248S. Seminar: Systems, Dynamics, and Control Topics. (2) Same as Chemical Engineering M297 and Mechanical and Aerospace Engineering M298A.) 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. (Sp)

CM250A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) Same as Bioengineering CM250A 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, 4BL, Introduction to micromachining technologies 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 micromachining processes capable of achieving desired MEMS device. Concurrently scheduled with course CM150. Letter grading. Mr. Candler (F)
M250B. Microelectromechanical Systems (MEMS) Fabrication. (Same as Bioengineering M250B and Mechanical and Aerospace Engineering M250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced prerequisite: course CM150 or CM250A. Advanced discussion of micromanufacturing processes used to construct MEMS. Coverage of many aspects of micromanufacturing fabrication and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/thermal stress. Letter grading. Mr. Candler (Sp)

CM250L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM250L and Mechanical and Aerospace Engineering CM250L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM250A, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4A, 4B. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromanufacturing and how these methods can be used to create 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 (F)


M255. Neuromechanics. (4) (Same as Bioengineering M260 and Neuroscience M206L.) Lecture, four hours; laboratory, three hours; outside study, five hours. Introduction to neuromechanics 32A, Physics 1C or 16B. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity, electro-physiology (action potentials, local field potentials, extracellular recording, intracellular and extracellular recording, microelectrode technology, neural signal processing (neural signal frequency bands, filtering, spike detection, spike sorting, stimulus artifact removal, brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading. Mr. Markovic (W)

M256A-M256B-M256C. Evaluation of Research Literature in Neuroengineering. (2-2-2) (Same as Bioengineering M256A-M256B-M256C and Neuroscience M212A-M212B-M212C.) Discussion, two hours; outside study, four hours. Critical discussion and analysis of current literature related to neuroengineering research. S/U grading. Mr. Markovic (F)

M257. Nanoscience and Technology. (4) (Same as Mechanical and Aerospace Engineering M287.) Lecture, four hours; outside study, eight hours. Enforced prerequisite: course CM250A. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication; nanocharacterization, nanoelectronics, and nanodevice technology. Band structure and bandgap energy of quantum wells, nanowires, and nanotubes. Introduction to new scientific and technological principles in nanoscale systems and devices. Letter grading. (Not offered 2013-14)

260A. Advanced Engineering Electrodynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M250A or CM250A. Advanced treatment of concepts in electrodynamics and their applications to modern engineering problems. Vector calculus in generalized coordinate system. Solutions of wave equations for potential and polarization. Reflection, transmission, and polarization. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, and sphere, including radiation cross-section characterization. Green's functions in electrodynamics and dyadic calculus. Letter grading. (Not offered 2013-14)

260B. Advanced Engineering Electromagnetics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 161, 162A, 260A. Advanced treatment of concepts and numerical techniques in electromagnetic field and wave propagation. Letter grading. (Not offered 2013-14)

261. Microwave and Millimeter Wave Circuits. (4) Lecture, four hours; outside study, eight hours. Requisite: course 163A. Rectangular and circular waveguides, microstrip, stripline, finline, and dielectric waveguide distributed circuits, with applications in microwave and millimeter wave integrated circuits. Substrate materials, surface wave phenomena. Analytical methods for discontinuity effects. Design of passive microwave and millimeter wave circuits. Letter grading. Mr. Aref'ev (W)


266. Computational Methods for Electromagnetics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 162A, 163A. Computational techniques for partial differential and integral equations: finite-difference, finite-element, method of moments. Applications include transmission line theory, resonant filters, microstrip devices, microwave antennas, modeling, electromagnetic scattering, and antennas. Letter grading. Mr. Itah (Sp)

270. Applied Quantum Mechanics. (4) Lecture, four hours; outside study, eight hours. Preparation: Modern Physics (or course 123A), linear algebra, and ordinary differential equations. Principles of quantum mechanics for applications in lasers, solid-state physics, and nonlinear optics. Topics include eigenfunction expansions, observables, Schrödinger equation, uncertainty principle, central force problems, Hilbert spaces, WKB approximation, matrix mechanics, density matrix formalism, and radiation theory. Letter grading. Mr. Williams (F)


279. 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 electromagnetic, microwave and millimeter wave electronics, photonic devices, optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. Mr. Dzhanidze (F)

279A. Seminar in 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 electromagnetic, microwave and millimeter wave electronics, photonic devices, optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. (Not offered 2013-14)

279CS. Clean Green IGERT Brown-Bag Seminar. (1) Seminar, one hour. Required of students in Clean Energy for Green Industry (IGERT) Research Literature seminar presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. Ms. Huftaker (F/Sp)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics 121. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave and millimeter wave plasma waves, ions acoustic waves, cyclotron waves, hydro-magnetic waves, drift waves, Rayleigh/Taylor, Kelvin/ Helmholtz, universal, and streaming instabilities. Application of experiments in fully and partially ionized gases. Letter grading. (Not offered 2013-14)

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 bounded 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 2013-14)


295. Academic Technical Writing for Electrical Engineers. (3) Seminar, three hours; outside study, three hours. Preparation: 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 a variety of genres, all related to their professional development as electrical engineers. Emphasis on writing as a vital way to communicate precise technical and professional information in distinct contexts, directly resulting in specific outcomes. S/U grading.

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 2013-14)

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 petitions available in Office of Graduate Student Affairs. S/U grading. Mr. Tabuada (F,W,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.

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate electrical engineering students. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate electrical 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 electrical 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 electrical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

Materials Science and Engineering

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Dwight C Streit, Ph.D., Chair
Mark S. Goorsky, Ph.D., Vice Chair
Suneel Kodambaka, Ph.D., Vice Chair

Professors
Russel E. Caflisch, Ph.D.
Gregory P. Carman, Ph.D.
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Yong Chen, Ph.D.
Bruce S. Dunn, Ph.D. (Nippon Sheet Glass Company Professor of Materials Science)
Nasr M. Ghoniem, Ph.D.
Mark S. Goorsky, Ph.D.
Vijay Gupta, Ph.D.
Robert F. Hicks, Ph.D.
Richard B. Kaner, Ph.D.
Ali Mostieh, Ph.D. (Evalyn Knight Professor of Engineering)
Vidvuds Ozolins, Ph.D.
Qibing Pei, Ph.D.
Dwight C. Streit, Ph.D.
Sarah H. Tolbert, Ph.D.
King-Ning Tu, Ph.D
Kang L. Wang, Ph.D. (Raytheon Company Professor of Engineering)
Paul S. Weiss, Ph.D.
Benjamin M. Wu, Ph.D., D.D.S., Ph.D.
Ya-Hong Xie, Ph.D.
Jenn-Ming Yang, Ph.D.
Yang Yang, Ph.D. (Carol and Lawrence E. Tannas, Jr. Endowed Professor of Engineering)

Professors Emeriti
Alan J. Ardell, Ph.D.
David L. Douglass, Ph.D.
William Klement, Jr., Ph.D.
Nasr M. Ghoniem, Ph.D.

Associate Professors
Yu Huang, Ph.D.
Debra Tannas, Jr., Endowed Professor of Engineering

Adjunct Professor
Harry Patton Gillis, Ph.D.

Adjunct Associate Professors
Eric P. Bescher, Ph.D.
Kosmas Galatsis, Ph.D.
**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 opto-electronic 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 systems of current and/or future importance to society, (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 Option**

**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, 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C.

**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, 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, 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 18 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.

**The Major**

**Required:** Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Electrical Engineering 101A, 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 170L, 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, 131A, Materials Science and Engineering C111, 143A, 162.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 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 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, 298.

Electronic and optical materials: Materials Science and Engineering C111, 121, 122, 143A, 151, 161, 162, 200, 201, 221, 222, 223, 298.


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, 101A, 102, 103, 110L, M116L, M171L, 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.

Thesis Plan

In addition to fulfilling the course requirements, under the thesis plan students are 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 multi-layer) 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 transmission 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 bonding
- 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, and 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 and characterization, thin film shape memory, nanoscale multifunctional, magnetoelectrics and piezoelectrical materials
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 nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits, and systems
Bruce S. Dunn, Ph.D. (UCLA, 1974)
Synthesis and characterization of electronic, magnetic, and magnetic materials, energy storage, sol-gel materials and chemical sensors
Masr M. Ghoniem, Ph.D. (Wisconsin, 1977)
Mechanical behavior of high-temperature materials, radiation interaction with materials (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 epitaxial 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 films and interfaces, failure mechanisms and characterization of composite materials, ice mechanics
Robert F. Hicks, Ph.D. (UC Berkeley, 1984)
Chemical vapor deposition and atmospheric plasma processing
Richard B. Kaner, Ph.D. (Pennsylvania, 1984)
Synthesis, characterization, and applications of superhard metals, conducting polymers, thermoelectrics and graphene
Reliability engineering, physics of failure modeling and simulation, life prediction, resilient systems design, prognostics and health monitoring, hybrid systems simulation, theories and techniques for risk and safety analysis
Vidushad Ozols, Ph.D. (Kungliga Tekniska Högskolan, Sweden, 1998)
Materials theory, computational materials design, materials for energy storage and generation, magnets and optical materials, thermoelectrics, mathematical models for atomistic simulations and electron heat transport, magnetic materials, computer learning, knowledge extraction
Qibing Pei, Ph.D. (Chinese Academy of Sciences, 1990)
Electroactive polymers through molecular design and nanoelectronics for electronic devices and artificial muscles
Dwight C. Streit, Ph.D. (UCLA, 1986)
Properties of electronic materials, characterization of materials 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, 3D packaging

Kang L. Wang, Ph.D. (MIT, 1970)

Nanoscale physics, materials and devices nanoelectronics, magnetics and photonics, nonlinear interactions of correlated devices and nanosystems

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 bioredox polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Ya-Hong Xie, Ph.D. (UCLA, 1986)

Physical properties and device application of graphene and other van der Waals materials; semiconductor physics, heterostructures, and devices; epitaxy of semiconductor thin films; nanofabrication

Jenn-Ming Yang, Ph.D. (Delaware, 1986)

Nanomechanical testing, nanostructured materials, ceramic and ceramic matrix composites, hybrid materials and composites, material synthesis and processing

Yang Yang, Ph.D. (Massachusetts-Lowell, 1992)

Organic and inorganic semiconductor materials and devices with emphasis on solution processes; fundamental understanding of material properties; optoelectronic devices (LEDs, P/VS, TFT, sensors)

Professors Emeriti

Alan J. Ardell, Ph.D. (Stanford, 1964)

Irradiation-induced precipitation, high-temperature deformation of solids, electron microscopy, physical metallurgy of aluminum/lithium alloys, precipitation hardening

David L. Doughlas, 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

John D. Mackenzie, Ph.D. (Imperial C., London, 1964)

Glass science, ceramics, electrical properties of amorphous materials, materials recycling

Kanj Ono, Ph.D. (Northwestern, 1964)

Mechanical behavior and nondestructive testing of structural materials, acoustic emission, dislocation 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

Alfred S. Yue, Ph.D. (Purdue, 1967)

Semiconductor devices and electronic materials for solar cell and detector applications, solidification and crystal growth

Associate Professors

Yu Huang, Ph.D. (Harvard, 2003)

Nanomaterial fabrication and development, bio-nano structures

Ioanna Kakouli, D.Phil. (U.Oxford, United Kingdom, 1999)

Chemical and physical properties of non-metallic architectural materials; alteration processes in archaeological vitreous materials and pigments

Suneel Kodamba, 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 hybrids

Kosmas Galalis, Ph.D. (MIT 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 of various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics.

19. Flat 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.

90L. Physical Measurement in Materials Engineering. (2) Laboratory, four hours; outside study, two hours. Various physical measurement methods used in materials science and engineering: thermal, electrical, magnetic, optical, and optical techniques. Letter 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

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.

110L. Introduction to Materials Characterization A (Crystal Structure, Nanostructures, and X-Ray Scattering). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course 104. Modern methods of materials characterization; fundamentals of crystallography, properties of X rays, X-ray scattering; powder method, Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading.

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, and special projects. Letter grading.

C111. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered 111T. 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, stereographic 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.


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 110 or (Chemistry 113A). Introduction to electrical, 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.

121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and ion-beam techniques. Heterojunction technologies, technology of high-gap engineering, development of new materials for optoelectronic applications. Letter grading.

122L. Materials Science of Semiconductors Laboratory. (2) Laboratory, two hours; outside study, three hours. Corequisite: course 121. Experiments conducted on materials characterization, including measurement of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.
122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 104, and Chemical Engineering 105A. Preparation 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, one hour; outside study, seven hours. Requisites: course 104, and Chemical Engineering 105A. Study of thermodynamic laws, equilibrium criteria, solution thermodynamics, mass action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Tu (F)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Corequisite: course 131. Preparation of materials, experimental design, study of self-diffusion, interdiffusion, grain boundary migration, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. Mr. Wu (W)


C133. Ancient and Historic Metals: Technology, Microstructure, and Corrosion. (4) Lecture, four hours; laboratory, 90 minutes. Processes of extraction, alloying, surface treatment, and corrosion. Discussion of an example of each. Laboratory work in preparation and examination of metallic samples under microscope, as well as lectures on technology of metalworking. Practical instruction in metallographic microscopy, including preparation of phase and stability diagrams of common alloying systems and environments and analytical techniques appropriate for examination and characterization of metallic artifacts. Concurrently scheduled with course CM333. Lecture grading.

140. Materials Selection and Engineering Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: at least two courses from 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymers, ceramic, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading. Mr. J-M. Yang (Sp)

141L. Computer Methods and Instrumentation in Materials Science and Engineering Laboratory. (4) Laboratory, four hours; lecture, two hours; Preparation: knowledge of BASIC or other computer language. Limited to junior/senior Materials Science and Engineering majors. Interface and control techniques, 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. Requisites: course 104, 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). Design, characterizing mechanical behavior of various materials; elastic and plastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. Ono

150. Introduction to Polymers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, structure crystalinity, and morphology and their effects on physical properties. Glass transition, springy polymers, elastomers, adhesives. Fiber forming polymers, polymer processing technology, plasticization. Letter grading. Mr. Pei (W)


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 engineering materials. Study of ceramic 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; outside study, seven hours. Corequisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting, Microstructure properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading. Mr. Dunn (Sp)

161L. Laboratory in Ceramics. (2) Laboratory, four hours; discussion, eight hours. Corequisite: course 161. Preparation of ceramics and glasses. Attainment of specific properties through process control for engineering applications. Quantitative characterization and selection of raw materials. Slip casting and extrusion of clay bodies. Sintering of powders. Glass melting and fabrication. Determination of chemical and physical properties. Letter grading. Mr. Lin (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Electrical Engineering 1 (or Physics 1C). Utilization of ceramics in modern electronic devices. High dielectric and magnetic properties, finishes, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferroelectric ceramics and electrooptic devices; optical wave guide applications. Letter grading. Mr. Dunn

170. Engaging Elements of Communication: Oral Communication. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive oral presentation and communication skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentations. Learning environment is highly supportive and interactive as it helps students creatively develop and, and expand great effectiveness of their communication and knowledge. Letter grading. Mr. Xie

171. Engaging Elements of Communication: Writing for Technical Community. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive technical writing skills on subjects specific to field of materials science and engineering. Students write review term paper in selected subject field of materials science and engineering from given set of journal publications. Instruction leads students through key steps, including background reading, choosing title, coming up with outline, concise writing of abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and argument. Letter grading. Mr. Xie

CM180. Introduction to Biomaterials. (4) (Same as Bioengineering CM178.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering of 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 CM280. Letter grading. Mr. Wu (W)

188. Special Courses in Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in materials science and engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students as part of their research experiences. Discussion of research methods and current literature in field or of research of faculty members or students. May be repeated for credit. Letter grading.

199. Directed Research in Materials Science and Engineering. (2 to 6) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. Occasionally field trips may be arranged. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (FWSp)

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 semiconductors, dielectric and magnetic properties of solids. Letter grading. Mr. Y. Yang (F)


210. Diffraction Methods in Science of Materials. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Requisite: course 110. Theory of diffraction of waves (X rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of plastic deformation, solid-state transformations, arrangements of atoms in liquids and amorphous solids. Letter grading. Mr. Goorsky (Sp, odd years)

C211. Introduction to Materials Characterization B (Electron Microscopy). (4) (Same as Bioengineering B211.) 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, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy: environmental and reflective modalities; electron optics of both instruments. Concurrently scheduled with course C111. Letter grading. Mr. Kodambaka (Sp, even years)

of materials characterization in conservation: optical and electron microscopy, X-ray and electron spectroscopy, X-ray fluorescence spectroscopy and multispectral imaging spectroscopy, chromatography, design of archaeo-
logical and ethnographic materials characterization
procedures. Concurrently scheduled with course C0112. Letter grading. Mr. Goorsky (W)

215. Techniques and Materials of Archaeo-
logical and Cultural Materials: In Situ and Ex Situ Ar-
chitectural Decorative Surfaces. (Same as Art History M203F and Conservation M250.) Seminar, two hours; laboratory, three hours. Requisites: courses M216 or C112 or Conservation M210. Recommended: Conservation M215. Designed for graduate con-
struction and art history students. Principles of ar-
cheological and cultural materials, with focus on rock art, wall paintings, polychrome sculp-
ture, decorative architectural elements, and mosaics, through study of their constituent material and tech-
niques in their context of geographical and chrono-
logical occurrence, technological developments, physical and conservation history, and physical loca-
tion. Lectures, case study-presentations, museum and site visits, hands-on laboratory experience, and independent research that incorpo-
rates literary survey of archaeological and conserva-
tion records, scientific data, and ancient treatises. Letter grading.

216. Science of Conservation Materials and Meth-
ods I. (Same as Conservation M216.) Semi-
inar, one hour; laboratory, three hours. Recommended re-
quisite: course 104. Introduction to physical, chem-
ical, and mechanical properties of conservation ma-
terials (employed for preservation of archaeological and cultural materials) and their aging characteristics. Science and application methods of traditional or-
ganic and inorganic systems and introduction of nov-
el technology based on biomimarization processes 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 of materials systems, and characterization. Letter grading. Mr. Goorsky (Sp)

222. Growth and Processing of Electronic Materi-
als. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 130, 131. Thermody-
namics and kinetics that affect semiconductor growth and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), het-
eroepitaxy, implantation, oxidation. Letter grading.

223. Materials Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131. Fabrication, structure, and prop-
erty correlations of thin films used in microelectronics for data and information processing. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading. Mr. Tu

244. Deposition Technologies and Their Applica-
tions. (4) Lecture, four hours; outside study, eight hours. Emphasis on the physics behind majority of modern thin film deposition technologies based on vapor phase transport. Basic vacuum technology and gas kinetics. Deposition methods used in high-tech-
nology electronics and experimental details of physical vapor physical deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition processes. Letter grading. Mr. Xie

255. Materials Science of Surfaces. (4) Lecture, four hours; outside study, eight hours. Requisites: course 120, Chemistry 113A. Introduction to atomic and electronic structure of surfaces. Survey of meth-
ods for determining composition and structure of sur-
faces and optimization of surface properties. Emphasis on scanning probe microscopy, Auger electron spectroscopy, X-ray photoelectron spectroscopy, secondary electron spectroscopy, X-ray fluorescence spectroscopy, and Rutherford backscattering spectrometry. Applications in microelectronics, optoelectronics, metallurgy, polymers, biological and biocompatible materials, and catalysis. Letter grading. Mr. Y. Yang (Sp)

256. Advanced Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: By permission of the instructor. Requisite: course 151. Fabrication methods, structure, and properties of advanced composite materials. Fibers, resin-, metal-, and ceramic-matrix composites. Physical, mechanical, and nondestructive characterization techniques. Letter grading. Mr. Pei (F)

257. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic polymers, bio- and nanostructured materials, and biomaterials and biocomposites. Extensive description and discussion of structure-property rela-
tionship, spectroscopic and experimental tech-
niques, and preparation methods for various soft ma-
terials. Letter grading. Mr. Pei (F)

270. Computer Simulations of Materials. (4) Lect-
ture, four hours; outside study, eight hours. Introduc-
tion to modern methods of computational modeling in materials science. Topics include basic statistical mechanics, classical molecular dynamics, and Monte Carlo methods, with emphasis on understanding ba-
sic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of ex-
amples from current literature will be stressed. These methods can be used to study interesting pheno-
mata in materials science. Hands-on computer experi-
mements. Letter grading. Mr. Ozolins (W)

271. Electronic Structure of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: basic knowledge of quantum mechanics. Recom-
manded requisite: course 200. Introduction to mod-
ern first-principles electronic structure calculations for various types of materials. Properties of electrons and interatomic bonding in molecules, crystals, and liquids, with emphasis on practical methods for solving Schrödinger equation and using it to calculate physical properties of solids. Monte Carlo methods, with emphasis on understanding ba-
sic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of ex-
amples from current literature will be stressed. These methods can be used to study interesting pheno-
mata in materials science. Hands-on computer experi-
mements. Letter grading. Mr. Ozolins (W)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Strongly recom-
manded requisite: course 200. Introduction to prop-
erties and applications of nanoscale materials, with emphasis on understanding of basic principles that distinguish nanomaterials (with feature size below 100 nm) from more conventional materials. This course will address the new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics in-
clude structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assem-
bley on surfaces and in liquid solutions, mechanical properties of nanostructured metamaterials, mole-
cular 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. CM280. Introduction to Biomaterials. (4) (Same as Bioengineering CM273S.) Lecture, three hours; discus-
sion, two hours; outside study, seven hours. Requi-
sites: course 39A, Chemistry 20A, 20B, and 201L. 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 CM180. Letter grading.

Mr. Wu (W)

282. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Researchers from leading research institutions around world deliver lectures on advanced research topics in materials science and engineering. Student groups present summary previews of topics prior to lecture. Class discussions follow each presentation. May be repeated for credit. S/U grading. Mr. J-M. Yang

296. Seminar: Advanced Topics in Materials Science and Engineering. (2) Seminar, two hours; outside study, four hours. Advanced study and analysis of current topics in materials science and engineering. Discussion of current research and literature in research specialty of faculty members teaching course. May be repeated for credit. S/U grading.

298. 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 apprentice ship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading.

596. 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.

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Reading and preparation for M.S. comprehensive examination. S/U grading.


597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.


599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

Mechanical and Aerospace Engineering

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Tetsuya Iwasaki, Ph.D., Vice Chair
Adrienne G. Lavine, Ph.D., Vice Chair

Professors
Mohamed A. Abdou, Ph.D.
Oddvar O. Bendiksen, Ph.D.
Gregory P. Carman, Ph.D.
Ivan Catton, Ph.D.
Jiun-Shyan Chen, Ph.D.
Yong Chen, Ph.D.
Vijay K. Dhir, Ph.D.
Dean Rajit Gadh, Ph.D.
Nasr M. Ghozien, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor of Aeronautics)
Tetsuya Iwasaki, Ph.D.
Y. Sungtaek Ju, Ph.D.
Ann R. Karagozian, Ph.D.
Chang-Jun (C-J) Kim, Ph.D.
J. John Kim, Ph.D. (Rockwell Collins Professor of Engineering)
Adrienne G. Lavine, Ph.D.
Kuo-Nan Liou, Ph.D.
Christopher S. Lynch, Ph.D.
Ajit K. Mai, Ph.D.
Robert T. M’Closkey, Ph.D.
Laurent G. Pilon, Ph.D.
Jason L. Speyer, Ph.D. (Ronald and Valerie Sugar Endowed Professor of Engineering)
Tsu-Chin Tsao, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti
Peretz P. Friedmann, Sc.D.
H. Thomas Hahn, Ph.D. (Raytheon Company Professor Emeritus of Manufacturing Engineering)

Walter C. Hurty, M.S.
Robert E. Kelly, Sc.D.
Michel A. Melkanoff, Ph.D.
Anthony F. Mills, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkevitz, Ph.D.
Philip F. O’Brien, M.S.
Lucien A. Schmit, Jr., M.S.
Owen I. Smith, Ph.D.
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.
Daniel C.H. Yang, Ph.D.

Assistant Professors
Jonathan B. Hopkins, Ph.D.
Richard E. Wiz, Ph.D.

Lecturers
Ravneesh C. Amar, Ph.D.
Amiya K. Chatterjee, Ph.D.
Carl F. Ruoff, Ph.D.
Judy I. Shane, M.S.

Adjunct Professors
Leslie M. Lackman, Ph.D.
Wilbur J. Marner, Ph.D.
Neil B. Morley, Ph.D.
Robert S. Shafer, Ph.D.
Ronald Szilard, Ph.D.

Adjunct Associate Professor
Gopinath R. Warrier, Ph.D.

Adjunct Assistant Professor
Abdon E. Sepulveda, Ph.D.

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. At 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: within a few years after graduation, the students will be successful in careers in aerospace or mechanical or other engineering fields, and/or in graduate studies in aerospace or mechanical or other engineering fields, and/or in 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; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, C150P, 150R or 161A, 154S, 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, 134, 135, 136, CM140, 150C, 150F, 150R, 153A, 154S, 155, 157A, 161A, 161B, 163A, 166C, M168, 169A, 171B, 172, 174, C175A, CM180, 181A, 182B, 182C, 183, 184, 185, C186, C187L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Mechanical Engineering B.S.

Capstone Major

The mechanical engineering program is designed to provide basic knowledge in thermodynamics, fluid mechanics, heat transfer, solid mechanics, mechanical design, dynamics, control, mechanical systems, manufacturing, and materials. The program includes fundamental subjects important to all mechanical engineers.

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: Electrical Engineering 110L, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 131A or 133A, 156A, 157, 162A, 171A, 182A, 183; 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 166A—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 162D, 162E); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131A (unless taken as a required course), 131AL, C132A, 133A (unless taken as a required course), 133AL, 134, 135, 136, CM140, 150A, 150B, 150C, C150G, C150P, 150R, 153A, 154S, 155, 157A, 161A, 161B, 163A, 166C, M168, 169A, 171B, 172, 174, C175A, CM180, 181A, 182B, 182C, 183, 184, 185, C186, C187L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 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 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, 152B, M171L, 199; Electrical Engineering 100, 101A, 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 C150P, (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 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.

**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 adviser, is established to administer the examination. Students may, in consultation with their adviser 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. Consult the department.

**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
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 been 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 micro-scale 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 electromagneto-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, bio-mechanics 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, wafering 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 filament 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 a ultra high-speed digitizer, sputter deposition chamber, 56 Kip 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 multi-axial 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 components, characterizing shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally validated microstructures

Ivan Catton, Ph.D. (UCLA, 1966)  
Heat transfer and fluid mechanics, transport phenomena in porous media, nucleic acids heat transfer, combination of thermal hydraulics, natural and forced convection, thermal/hydraulic stability, turbulence

Jiun-Shyan (J-S) Chen, Ph.D. (Northwestern, 1989)  
Finite element methods, mesh free methods, large deformation mechanics, inelasticity, contact problems, structural dynamics

Yong Chen, Ph.D. (U.C. Berkeley, 1996)  
Nanoscale science and engineering, micro- and nanofabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems

Jeff D. Eldredge, Ph.D. (Caltech, 2002)  
Numerical simulation of fluid dynamics, bio-inspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vortexity-based numerical methods, simulations of biomedical flows

H. Pirouz Kavehpour, Ph.D. (MIT, 2003)  
Microscale fluid mechanics, transport phenomena in biological systems, physics of contact line phenomena, complex fluids, non-isothermal flows, micro- and nano-heat guides, microbiology

Computational structural and solid mechanics, finite element methods, computational biomechanics, nanomechanics of biological systems

Mechanical and Aerospace Engineering / 101

Tetsuya Iwasaki, Ph.D. (Purdue, 1993)  
Dynamical systems, robust and optimal control, nonlinear oscillators, resonance entrainment, modeling and analysis of neuronal control circuits for animal locomotion, central pattern generators, body-fluid interaction during undulatory and oscillatory swimming

Y. Sungtaek Ju, Ph.D. (Stanford, 1978)  
Turbulence, numerical simulation of turbulent and transitional flows, application of control theories to flow control

Adrienne Lavine, Ph.D. (U.C. Berkeley, 1984)  
Heat transfer: thermomechanical behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection

Kuo-Nan Liou, Ph.D. (New York U., 1970)  
Radiative transfer and satellite remote sensing with application to clouds and aerosols in the earth’s atmosphere

Christopher S. Lynch, Ph.D. (U.C. Santa Barbara, 1992)  
Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensor and actuator applications, fracture mechanics and failure analysis

Ajit K. Mal, Ph.D. (Calcutta U., 1964)  
Mechanics of solids, fractures and failure, wave propagation, nondestructive evaluation, composite materials

Robert T. M’Closkey, Ph.D. (Caltech, 1995)  
Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation

Laurent G. Plion, Ph.D. (Purdue, 2002)  
Interfacial and transport phenomena, radiation transfer, materials synthesis, multi-phase flow, heterogeneous materials

Jason L. Speyer, Ph.D. (Harvard, 1968)  
Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Tsu-Chin Tsao, Ph.D. (U.C. Berkeley, 1988)  
Computational fluid dynamics, hypersonic flow, rarefied gas dynamics, numerical simulation of transient hypersonic flow with nonequilibrium real gas effects, instability of hypersonic boundary layers

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

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)  
Experimental in noise control, physical acoustics, engineering acoustics, medical acoustics

Russell A. Westmann, Ph.D. (U.C. Berkeley, 1962)  
Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems

Daniel C.H. Yang, Ph.D. (Rutgers, 1982)  
Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1989)  
Fabrication technologies, structures, actuators, base design, relational models, simulation systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Computational structural and solid mechanics, finite element methods, computational biomechanics, nanomechanics of biological systems

Lecturers

Ravmesh C. Amar, Ph.D. (UCLA, 1974)  
Heat transfer and thermosyphon

Amya K. Chatterjee, Ph.D. (UCLA, 1976)  
Elastic wave propagation and penetration dynamics

Carl F. Ruoff, Ph.D. (Caltech, 1993)  
Robotics, computing, mechanical design, instrument technology, technology management

Adjunct Professors

Leslie M. Lackman, Ph.D. (U.C. Berkeley, 1967)  
Structural analysis and design, composite structures, engineering management

William J. Marner, Ph.D. (Caltech, 1969)  
Thermal sciences, system design

Neil B. Morley, Ph.D. (UCLA, 1994)  
Experimental and computational fluid mechanics

Robert S. Shaffer, Ph.D. (UCLA, 1985)  
Radiation interaction with materials, microstructure evolution modeling, plasma and laser processing, fusion technology research, fusion
principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

135A. Control Theory. (4) Lecture, two hours; discussion, two hours; outside study, six hours. Requisites: courses 105D, 157 or 157S. Experimental study of power conversion and heat transfer systems using state-of-art plant process instrumentation and equipment. Experiments include studies of thermodynamic operating characteristics of actual Brayton cycle engine cycle, compressive refrigeration unit, and absorption refrigeration unit. Letter grading. 

Mr. Catton (Sp)

134. Design and Operation of Thermal Hydraulic Power Systems. (4) Lecture, laboratory, three hours; outside study, six hours. Requisites: courses 133A, 133AL. Thermal hydraulic design, maintenance and operation of power systems, gas turbines, steam turbines, absorption units, absorption refrigeration units, compressors, valves and piping systems, and instrumentation and control systems. Letter grading.

Mr. Catton

135. Fundamentals of Nuclear Science and Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: 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, fuel cells, transportation, energy conservation, and water pollution, global warming. Letter grading.

Mr. Abdou (F)

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: 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, fuel cells, transportation, energy conservation, and water pollution, global warming. Letter grading.

CM140. Introduction to Biomechanics. (4) (Same as Bioengineering CM140) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 101, 102, 156A. Introduction to biomechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics, fluid, thermal, and electrical systems. Description of physical systems, with examples of mechanical, electrical, and open systems. Letter grading. 

Mr. Catton


Mr. Elderidge, Ms. Karagozian (F,W)

150B. Aerodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: courses 103, 150A. Advanced aspects of potential flow theory. Incompressible flow around thin airfoils (lift and moment coefficients) and wings (lift, induced drag). Gas dynamics: oblique shocks, Prandtl-Meyer expansion, and supersonic flow around thin airfoils and wings. Wave drag, Transonic flow. Letter grading. 

Mr. Zhong (Sp)


Ms. Karagozian (Not offered 2013-14)
C150G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: courses of aquatic ecosystems, insect and bird flight aerodynamics; pulsatile flow in circulatory system; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial diseases. Concurrently scheduled with course C250G. Letter grading. Mr. Ghoniem (Not offered 2013-14)  
C150P. Aircraft Propulsion Systems. (4) Formerly numbered 150P. Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Thermal properties of aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C250P. Letter grading. Ms. Kargozarian  
15OR. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103, 105A. Not open to students with credit for both courses 161B and 161R. Rocket propulsion concepts, including chemical 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. Mr. Tsao (W)  
153A. Engineering Acoustics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Design of electronic and mechanical systems. Estimation, measurement of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Ghoniem (W)  
157A. Fluid Mechanics and Aerodynamics Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 150A and 157 or 157S. Experimental illustration of important physical phenomena in area of fluid mechanics/aerodynamics, as well as hands-on experience with design of experiments and use of modern experimental tools and techniques in field. Letter grading. Mr. Kavehpour  
157S. Basic Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 101, 102, 103, 105A. Electrical Engineering 100. Recommended: course 15. Measurements of basic physical quantities in fluid mechanics, thermodynamics, and structures. Operation 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 structures and materials relevant to aerospace engineering. Letter grading. Mr. Ju (W)  
161A. Introduction to Aeronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended: prerequisite course 182A. Space environment of Earth, trajectories and orbits, step rockets and staging, two-body problem, orbital transfer and rendezvous, problem of three bodies, elementary perturbation theory, influence of Earth's oblateness. Letter grading. Mr. Tsao (Not offered 2013-14)  
164A. 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 estimation, performance and stability, and control considerations. Term assignment consists of preliminary design of low-speed aircraft. Letter grading. Mr. Bendiksen  
154S. Aircraft Structures, Stability, and Dynamic Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and dynamic analysis. Basic aerodynamic concepts for design of aircraft. Effects of airplane flexibility on stability. Letter grading. Mr. Bendiksen  
155. Intermediate Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102. Analysis of Newtonian mechanics, generalized coordinates, Lagrange equation, variational principles; central force motion; kinematics and dynamics of rigid bodies. Euler equations, motion of rotating bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading. Mr. Gibson  
156A. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 101, 182A. Not open to students with credit for course 166A. Concepts of stress, strain, and material behavior. Stress in loaded beams with symmetric and asymmetric cross sections. Fatigue and fatigue crack initiation and growth. Fatigue of structures, shear flow. Stresses in pressure vessels, press-fit and shrink-fit problems, rotating shafts. Curved beams. Contact stresses. Strength and failure of composites, thermodynamic, elastic, and plastic instability. Letter grading. Mr. Mal (F)  
157. Basic Mechanical Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisite: courses 101, 102, 103A, 105A, 105D. Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Ghoniem (W)  
158. Fluid Mechanics and Heat Transfer Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 150A, 150B, 151A, 151B. Fluid flow through pipes and complex geometries, heat transfer and fluid flow. Letter grading. Mr. Tsao  
159A. Fluid Mechanics and Heat Transfer Laboratory. (4) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 150A, 150B, 151A, 151B. Fluid flow through pipes and complex geometries, heat transfer and fluid flow. Letter grading. Mr. Tsao  
162A. 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. Lectures on engineering project management, design of thermal systems, mechanical systems, and computer design projects. Students work in teams to begin their two-term design project. Laboratory modules include CAD design, CAD analysis, mechatronics, and conceptual design for team project. Letter grading. Mr. Sosa (W)  
162E. Mechanical Engineering Design II. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 162E. Limited to seniors. Second of two mechanical engineering capstone design courses. Students get to choose and design projects started in course 162D, making use of CAD design laboratory, CAD analysis laboratory, and mechatronics laboratory. Design theory, design tools, economic analysis, and intellectual property, design for manufacture and assembly, design for safety and reliability, and engineering ethics. Students conduct hands-on design, fabrication, and testing. Culminating project demonstrations or competition. Preparation of design project presentations in both oral and written formats. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)  
163A. Introduction to Computer-Controlled Machines. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite or corequisite: course 171A. Model of computer-controlled machines, including electrical and electronic elements, mechanical elements, actuators, sensors, and overall electromechanical systems. Motion and command generation, servo-controller design, and computer/machine interfacing. Letter grading. Mr. Ghoniem  
166A. Analysis of Flight Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 182A. Not open to students with credit for course 156A. Introduction to two-dimensional elasticity, stress analysis, yield and fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled cross sections: shear flow; shear-lag; combined bending torques of thin-walled, stiffened structures used in aerospace vehicles; elements of plate theory; buckling of columns. Letter grading. Mr. Carman (W)  
166C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, failure analysis, design examples and design studies, buckling of composite components, nonsymmetric laminates, micromechanics of composites. Letter grading. Mr. Carman (W)  
M168. Introduction to Finite Element Methods. (4) Laboratory, seven hours; discussion, one hour; outside study, seven hours. Requisite: course 156A or 166A or Civil Engineering 130. Introduction to basic concepts of finite element methods (FEM) for structural analysis of beams, plates, 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; preprocessing and postprocessing techniques; term projects with computers. Letter grading. Mr. Chen, Mr. Kug (F)  
169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101, 102, 103A, 105A. Fundamentals of vibration theory and applications. Free, forced, and transient vibration of one and two degrees of freedom systems, including damping. Normal modes, coupled vibrations, vibration isolation devices, vibrations of continuous systems. Letter grading. Mr. Bendiksen
locus methods; compensation; computer-aided analysis and design. Letter grading.

Mr. McClokey (F/W/Sp)

171B. Digital Control of Physical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 171A or Electrical Engineering 141. Analysis and design of digital control systems. Z-transform theory; Discrete-time system representation. Design using classical methods: performance specifications, root locus, frequency response, loop-shaping compensa-
tion. Design using state-space methods: state feed-
back, state estimator, state estimator feedback con-
trol. Simulation of sampled data systems and practi-
cal aspects: roundoff errors, sampling rate selection, computation delay. Letter grading.

Mr. Tsao (Not offered 2013–14)

172. Control System Design Laboratory. (4) Lecture, three hours; laboratory, two hours; outside study, seven hours. Enforced requisite: course 171A. Introduction to loop-shaping controller design with application to laboratory electromechanical systems. Power spectrum models of noise and disturbances, and performance trade-offs imposed by conflicting requirements. Constraints on sensitivity function and comple-
mentary sensitivity function imposed by non-
minimum phase plants. Lecture topics supported by weekly hands-on laboratory work. Letter grading.

Mr. McClokey (F/W/Sp)

174. Probability and Its Applications to Risk, Reli-
ability, and Quality Control. (4) Lecture, four hours; dis-
cussion, two hours; outside study, six hours. Requi-
site: Mathematics 33A. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-
strength interactions, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading.

Mr. Bendiksen, Mr. Gupta (W)

C175A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; out-
side study, eight hours. Enforced requisite: courses 107, 182A. Probability spaces, random variables, stochas-
tic processes and sequences, expectation, conditional expectation, Gaussian Markov sequence, and minimum variance estimator (Kalman filter) with applica-
tions. Concurrently scheduled with course C271A. Letter grading. Mr. Sprey (F)

CM180. Introduction to Micromachining and Mi-
croelectromechanical Systems (MEMS). (4) Same as Bioengineering CM150 and Electrical Engineering CM150.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20C, Computer Science 31. Introduction to micromachining technologies and microelectrome-
chanical systems (MEMS). Methods of micromachin-
ing and how these methods can be used to produce variety of MEMS, including microstructures, micro-
sensors, and microactuators. Students design micro-
fabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM280A. Letter grading. Mr. Chio (F)

CM180L. Introduction to Micromachining and Mi-
croelectromechanical Systems (MEMS) Labora-
tory. (2) (Same as Bioengineering CM150L and Electrical Engineering CM150L.) 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 microma-
chin welding, laser welding, and micromachining of microchips and microactuators. Students design and fabricate MEMS device. Concurrently scheduled with course CM280L. Letter grading.

Mr. Chio (F)

181A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 182A. Complex variables, analytic functions, conformal mapping, contour inte-
grals, singularities, residues, Cauchy integrals; La-
place transform: properties, convolution, inversion; Fourier transform; properties, convolution, FFT, appli-
cations in dynamical systems, structures, and heat conduction. Letter grading.

Mr. Ghoniem (Not offered 2013–14)

182A. Mathematics of Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hour.

Mr. Ng (Sp)

182B. Mathematics of Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 182A. Analytical methods for solving partial differential equations arising in engineering. Separation of variables, eigen-
value problems, Sturm-Liouville theory. Development and use of special functions. Representations by means of orthonormal functions; Galerkin method. Use of Green’s function and transform methods. Let-
ter grading.

Mr. Eldredge, Mr. J. Kim (W)

182C. Numerical Methods for Engineering Appli-
cations. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enrolled: course 182A, Computer Science 31. Recommended: Electrical Engineering 103. Basic topics from numerical analysis having wide application in solution of practi-
cal engineering problems, computer arithmetic, and errors. Solution of linear and nonlinear systems. Alge-
braic eigenvalue problem. Least-square methods, numerical quadrature, and finite difference approxi-

Mr. Zhong (F)

183. Introduction to Manufacturing Processes. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisite: Materials Sci-
ence 104. Manufacturing fundamentals. Materials in manufacturing, Manufacturing systems. Rapid proto-
typing, Material removal processes, Solidification and form-
ing, Joining and assembly, Particulate and sur-

Mr. C.-J. Kim (W/Sp)

184. Introduction to Geometry Modeling. (4) Le-
cure, four hours; laboratory, four hours; outside study, four hours; laboratory, one hour. Enforced requisite: Computer Science 31. Fundamentals in parametric curve and surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transfor-
ations, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and im-
plementation. Letter grading.

Mr. Gad (Not offered 2013–14)

185. Introduction to Radio Frequency Identifi-
cation and Its Application in Manufacturing and Supply Chain. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requi-
site: Computer Science 31. Manufacturing today re-
quires assembling of individual components into as-
sembled products, shipping of such products, and eventually disposing of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and as-
sembles of products allow them to be tracked auto-
matically as they move through manufacturing and dis-
tribution supply chain. RFID tags have memory and small CPU that allows information about product sta-
tus to be written, stored, and transmitted wirelessly. Tag readers identify the tag and can enter-
prise 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. Gad (F)

C196. Applied Optics. (4) Lecture, four hours; dis-
cussion, two hours; outside study, six hours. Requi-
site: Physics 1C. Fundamental principles of optical systems. Geometric optics and aberration theory. Dif-
fraction and interference. Fourier optics, beam op-
tics. Propagation of light, Snell’s law, and Huygen principle. Reflection and refraction, spherical waves, total internal reflection. Polarization, polarizers, and wave-plates. Lenses and aberrations, lens laws and formation of images, resolution and primary aberrations. Simple optical instruments, collimated and focus images, Design of telescopes, microscope design, projection system design. Inteference, Young’s slit experiment and fringe visibility. Michelson interferometer, multi-
ple-beam interference and thin film coatings. Diffrac-
tion theory, Fraunhofer and Fresnel diffraction, Fres-

Mr. Chiov (Not offered 2013–14)

C187L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and bio-
 logical principles related to these techniques, top-
down and bottom-up (self-assembly) nanofabrica-
tion, nanocharacterization (AEM, SEM, etc.), and opti-
cal and electrochemical biosensors. Students en-
courage to create their own sinter and designed experiments. Concurrently scheduled with course C287L. Letter grading.

Mr. Y. Chen (F/Sp)

188. Special Courses in Mechanical and Aero-
space Engineering. (2 to 4) Tutorial, two to four hours; outside study, four to eight hours. Special top-
ics in mechanical and aerospace engineering for un-
dergraduate students taught on experimental or tem-
orary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. P/NP or letter grading.

(Not offered 2013–14)

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 8) Tutorial, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of proj-
ects in research specialty. May be repeated for credit. P/NP or letter grading.

199. Directed Research in Mechanical and Aero-
space Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual re-
search or investigation under guidance of faculty men-
tor. Culminating paper or project required. May be repeated for credit with school approval. Individu-
al contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.

(F/W/Sp)

Graduate Courses

231A. Convective Heat Transfer Theory. (4) Lecture, four hours; outside study, eight hours. Requi-
sites: courses 131A, 182B. Recommended: course 250A. Conservation equations for flow of real fluids. Analysis of heat transfer in laminar and turbulent, in-
compressible and compressible flows. Internal and external flows; free convection. Variable wall tem-
perature; effects of variable fluid properties. Analog-
ous problem using convective transfer properties. Letter grading.

Ms. Lavine (W)

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 1182D. Radiative properties of materials, energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiative transfer in absorbing, scat-
ting, and scattering media. Applications cover las-
er-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading.

Mr. Pilon (Sp)

231C. Phase Change Heat Transfer and Two-
Phase Flow. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Two-
phase flow, boiling, and condensation. Generalized
constitutional equations for two-phase flow. Phenome-
nological theories of boiling and condensation,
including forced flow effects. Letter grading.

Mr. Catton (F)

231G. Microscopic Energy Transport. (4) Lecture,
four hours; outside study, eight hours. Requisite:
course 105D. Heat carriers (photons, electronics,
phonons, and molecules) and their energy charac-
teristics, statistical properties of heat carriers, scattering and
propagation of heat carriers, Boltzmann transport equations,
derivation of classical laws from Boltzmann
transport equations, deviation from classical
laws at small scale. Letter grading.

Mr. Ju (Sp)

C232A. Mass Transfer. (4) Lecture; four hours;
outside study, eight hours. Requisites: courses 105D,
131A. Principles of mass transfer by diffusion and
correlation and design of high heat flux components, energy
transport in multicomponent systems. Thermal,
forced, and pressure diffusion, Brownian diffusion.
Analysis of evaporative and tranpiration cooling, ca-
talytic, and combustion. Mass exchangers, including
automobile catalytic converters, electrostatic precipi-
tators, filters, scrubbers, humidifiers, and cooling
towers. Concurrently scheduled with course C132A.
Letter grading.

Mr. Pilon (F)

235A. Nuclear Reactor Theory. (4) Lecture;
four hours; outside study, eight hours. Requisite:
course 182A. Underlying physics and mathematics of nucle-
ar reactions and fission. Nuclear reactor design; Diffusion theory,
reactor kinetics, slowing down and thermalization, multi-
group methods, introduction to transport theory.
Letter grading.

Mr. Abdou M237B. Fusion Plasma Physics and Analysis. (4)
(Same as Electrical Engineering M237) Lecture;
four hours; outside study, eight hours. Requisite:
Electrical Engineering M185. Fundamentals of plasmas
at thermonuclear burning conditions. Fokker/Planck
equation and applications to heating by neutral
beams, RF, and fusion reaction products. Brems-
strahlung, synchrotron, and atomic radiation pro-
cesses. Plasma surface interactions. Fluid descrip-
tion of plasmas. Fluid dynamics, stability, and con-
trol. Applications in tokamaks, tandem mirrors, and
alternate concepts. Letter grading.

Mr. Abdou

237D. Fusion Engineering and Design. (4) Lecture;
four hours; outside study, eight hours. Fusion reac-
tions and fuel cycles. Principles of inertial and mag-
etic fusion. Plasma requirements for controlled fu-
of nuclear waste, fusion reactor concepts and
conversion and tritium breeding components, radia-
tion shielding, magnets, and heating. Letter grading.

Mr. Abdou (W)

239B. Seminar: Current Topics in Transport Pheno-
mena. (2 to 4) Seminar; two to four hours; outside
study, four to eight hours. Designed for graduate mec-
hanical and aerospace engineering students. Lect-
tures, discussions, student presentations, and proj-
etics in areas of current interest in transport phenom-
ena. May be repeated for credit. S/U grading.

Mr. Gibson (Sp)

239F. Special Topics in Transport Phenomena. (2 to
4) Lecture, two to four hours; outside study, four to
eight hours. Designed for graduate mechanical and
aerospace engineering students. Advanced and cur-
rent study of one or more aspects of heat and mass
transfer, such as turbulence, stability and transition,
buoyancy effects, variational methods, and measure-
ment techniques. May be repeated for credit with
topic change. S/U grading.

Mr. Eldredge

239G. Special Topics in Nuclear Engineering. (2 to
4) Lecture, two to four hours; outside study, four to
eight hours. Designed for graduate mechanical and
aerospace engineering students. Advanced study in
areas of current interest in nuclear engineering, such as
reactor safety, risk-benefit trade-offs, nuclear ma-
tериалы, and reactor design. May be repeated for
credit with topic change. S/U grading.

Mr. Eldredge

239H. Special Topics in Fusion Physics, Engineer-
ing, and Technology. (2 to 4) Seminar; two to four
hours; outside study, four to eight hours. Designed
for graduate mechanical and aerospace engineering
students. Advanced treatment of subjects selected
from research areas in fusion science and engineer-
ning, such as instabilities in burning plasmas, alternate fusion concepts, advanced inter-
fusion, fusion-fusion hybrid systems, and fusion reac-
tor safety. May be repeated for credit with topic change.
S/U grading.

Mr. Kavehpour

C250P. Aircraft Propulsion Systems. (4) Lecture;
four hours; discussion, two hours; outside study, six
hours. Requisites: courses 105A, 150A. Thermody-
namic properties of gases, aircraft jet engine cycle
analysis and component performance, component
matching and advanced aircraft engine turbomachinery.
Concurrently scheduled with course C150P. Letter
grading.

Ms. Karagozian (F)

252A. Stability of Fluid Motion. (4) Lecture; four
hours; outside study, eight hours. Requisite:
course 105A. Mechanisms by which laminar flows can
become unstable and lead to turbulence of secondary
flows. Linear stability theory; thermal, centrifugal,
and shear instabilities; boundary layer instability.
Nonlinear aspects: sufficient criteria for stability, sub-
critical instabilities, supercritical states, transition
to turbulence. Letter grading.

Mr. Zhong

252B. Turbulence. (4) Lecture; four hours;
outside study, eight hours. Requisite: courses 255A, 250B.
Characteristics of turbulent flow. Introduction to
turbulent flows, scales of turbulent motion, simple
turbulence phenomena, wakes, boundary layers,
turbulence modeling, numerical simulations of
turbulent flows, and turbulence control. Letter grading.

Mr. J. Kim (Sp)

252C. Fluid Mechanics of Combustion Systems. (4)
Lecture, four hours; outside study, eight hours.
Requisites: courses 105A, 150B. Recommended:
course 255C. Review of fluid mechanics and chem-
ical thermodynamics applied to reactive systems,
landmark combustion flames, flames, and
inertial confinement fusion. Turbulence modeling,
stability, ignition, turbulent combustion, supersonic
combustion. Letter grading.

Ms. Karagozian (F)

252D. Combustion Rate Processes. (4) Lecture;
four hours; outside study, eight hours. Requisite:
course 252C. Basic concepts in chemical kinetics;
molecular collisions, distribution functions and aver-
ging, semiempirical and ab initio potential surfaces,
trajectory calculations, statistical reaction rate theo-
ries. Practical examples of large-scale chain mecha-
nisms from combustion chemistry of several ele-
ments, etc. Letter grading.

Ms. Karagozian

254A. Special Topics in Aerodynamics. (4) Lecture;
four hours; outside study, eight hours. Requisites:
courses 150A, 150B, 182A, 182B, 182C. Special top-
ics of current interest in advanced aerodynamics. Ex-
amples include transonic flow, hypersonic flow, sonic
booms, and unsteady aerodynamics. Letter grading.

Mr. Zhong (W)

255A. Advanced Dynamics. (4) Lecture; four hours;
outside study, eight hours. Requisites: courses 155, 189A.
Variational principles and Lagrange equations.
Kinematics and dynamics of rigid bodies; procession
and nutation of spinning bodies. Letter grading.

Mr. Gibson (Sp)

255B. Mathematical Methods in Dynamics. (4) Lecture;
four hours; outside study, eight hours. Requi-
tes: course 255A. Concepts of stability; state-
space interpretation; stability determination by simu-
lization, linearization, and Lyapunov direct method;
the Hamiltonian as a Lyapunov function; nonautonomous
systems; averaging and perturbation methods of
nonlinear analysis; parametric excitation and nonlin-
ear resonance. Application to mechanical systems.
Letter grading.

Mr. M’Closkey

M256A. Linear Elasticity. (4) (Same as Chemical Engi-
neering M256A) Lecture; four hours; outside study,
eight hours. Requisite: course 156A or 166A. Linear
elastostatics. Cartesian tensors; infinitesimal strain
tensor; Cauchy stress tensor; strain energy; equilibri-
um equations; linear constitutive relations; plane
elastostatic problems, holes, corners, inclusions,
cracks; three-dimensional problems of Kelvin, Bous-
sinesq, and Cerruti. Introduction to boundary integral
equation method. Letter grading.

Mr. Mai (F)
256B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics 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 energy relations, and constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Mr. Mal (W)

256C. Plasticity. (4) (Same as Civil Engineering M230C.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Classical rate-independent plasticity theory, yield functions, flow rules, finite element methods, and rate-dependent viscoplasticity, Perzyna and Duvaut/Lions types of viscoplasticity. Thermoplasticity and creep. Return mapping algorithms for plasticity and visco-plasticity. Finite element implementations. Letter grading. Mr. Gupta

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. Klig (Sp)

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 equa- tion of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves in unbounded isotropic, anisotropic, and dissi- pative solids. Half-space problems. Guided waves in layered media. Applications to dynamic fracture, non-destructive evaluation (NDE), and mechanics of earthquakes. Letter grading. Mr. Mal

258A. Nanomechanics and Micromechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materi- als at scales ranging from atomic through micro-structure or transitional and up to continuum. Discuss- ion of atomistic simulation methods (e.g., molecular dynamics, Langevin dynamics, and kinetic Monte Carlo) and their applications at nanoscale. Develop- ments and implementation of new and existing statistical mechanics methods in areas of nanostruc- ture and microstructure self-organization, heteroge- neous plastic deformation, material instabilities, and failure phenomena. Integration of techniques and applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, disloca- tions and defects, surface growth, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical ther- mal barrier coatings and ultrathin nanolayer mate- rials), nano-identification, smart (active) materials, nanobending and microbending, and torsion. Letter grading. Mr. Ghosh

259A. Seminar: Advanced Topics in Fluid Mechan- ics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assign- ments in writing leading to term papers or oral presentation (possible help from guest lecturers). Letter grading. Mr. Kavehpour (W)

259B. Seminar: Advanced Topics in Solid Mechan- ics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid me- chanics on topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability of structures. Letter grading. Mr. Mal

260. Current Topics in Mechanical Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, dis- cussions, and student presentations and projects in areas of current interest in mechanical engineering. May be repeated for credit. S/U grading.


263A. Analytical Foundations of Motion Control- lers. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: courses 163A, 294. Theory of motion control for modern computer-con- trolled machines; multiaxis computer-controlled ma- chines; machine kinematics and dynamics; multiaxis motion coordination; coordinated motion with de- sired speed and acceleration; jerk analysis; motion command generation and design of controller inter- polators; 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. Recommended: course 255A. Modeling, dynamics, and stability of spacecraft; spinning and dual-spin space- craft dynamics; spinup through resonance, spin-up and spin-down, internal torques in space, modeling and model reduction of flexible space structures. Letter grading. Mr. Wirz

263C. Mechanics and Trajectory Planning of In- dustrial Robots. (4) Lecture, four hours; outside study, eight hours. Recommended: course 255A. Theory and implementation of industrial robots. Design con- siderations. Kinematic structure modeling, trajectory planning, and system dynamics. Differential motion and static forces. Individual student study projects. Letter grading. Mr. Ghoniem

263D. Advanced Robotics. (4) Lecture, four hours; outside study, eight hours. Recommended prepara- tion: courses 155, 171A, 263C. Motion planning and control of articulated dynamic systems; nonlinear joint control, experiments in joint control and multiax- is coordination, multibody dynamics, trajectory plan- ning and transient response, motion planning and manipulator design, kinematic redundancies, motion planning of manipulators in space, obstacle avoid- ance. Letter grading. Mr. Ghoniem

M269A. Dynamics of Structures. (4) (Same as Civil Engineering M237A.) Lecture, four hours; outside study, eight hours. Requisite: course 169A. Principles of dynamics. Determination of normal modes and fre- quencies by differential and integral equation solu- tions. Transient and steady state response. Emphasis on derivation and solution of governing equations us- ing matrix formulation. Letter grading. Mr. Bendiks (F)


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 air- loads from governing variational principles. Flow in- duced instability and response of structural systems. Letter grading. Mr. Bendiks

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engi- neering 240A.) Lecture, four hours; outside study, eight hours. Requisite: course 171A or Electrical Engi- neering 111. State-space, time-invariant (LTI) and time- varying (LTV) systems in con- tinuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular values, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observabil- ity, realizability, and minimality. Stabilization design via state feedback and observers; separation princi- ple and connections with transfer function models. Letter grading. Mr. M’Closkey (F)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A. Theory and applications of control systems for continuous-time and dis- crete-time systems, transient and infinite-time prob- lems; Hamiltonian systems and optimal control; alge- braic and differential Riccati equations; implications of controllability, stabilizability, observability, and detect- ability solutions. Letter grading. Mr. Gibson (W)

M270C. Optimal Control. (4) (Same as Chemical Engineering M280C and Electrical Engineering M240C.) Lecture, four hours; outside study, eight hours. Requisite: course 270B. Applications of varia- tional methods, Pontryagin maximum principle, Ham- ilton-Jacobi-Bellman equations (dynamic program- ming) to optimal control of dynamic systems mod- eled by nonlinear ordinary differential equations. Letter grading. Mr. Speyer

C271A. Probability and Stochastic Processes in Dynamic Systems. (4) (Formerly numbered 271A.) Lecture, four hours; outside study, eight hours. En- forced requisites: courses 107, 182A. Probability spaces, random variables, stochastic sequences and processes, expectation, conditional expectation, Gauss/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concur- rently scheduled with course C271A. Letter grading.

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course C271A. Linear and nonlinear estimation theory, or- thogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W)


271D. Seminar: Special Topics in Dynamic Sys- tems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling and control applica- tions. Topics selected from process control, differen- tial games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical Engi- neering 242A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering 240A. State-space techniques for studying solutions of
time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lapunov theory (including Lyapunov functions), invariance, center manifold theorem, input-to-state stability and small gain theorem. Letter grading.

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Prerequisites: courses 171TA, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representation, 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. Methods for identification of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of convergence to continuous-time models. Models identified include transfer functions and state-space models. Discussion of applications in mechanical and aero space engineering, including identification of flexible structures, micro electromechanical systems (MEMS) devices, and acoustic ducts. Letter grading. Mr. Gibson (Sp)


277. Advanced Digital Control for Mechatronic Systems. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Prerequisites: courses 171B, M270A. Digital signal processing and control analysis of mechatronic systems. System inversion-based digital control algorithms and robustness properties, Yosla parameterization of stabilizing controllers, previewed optimal feedback compensator, repetitive and learning control, and adaptive control. Real-time control investigation of topics to selected mechatronic systems. Letter grading. Mr. Tsao (W)

279. Dynamics and Control of Biological Oscilla tions. (4) Lecture, four hours; outside study, six hours; outside study, seven hours. Prerequisites: courses 107, M270A. Analysis and design of dynamical mechanisms underlying biological control systems that generate coordinated oscillations. Nonlinear information processing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, optimal gait (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Iwasaki (Sp)

CM280A. Introduction to Micromachining and Mi croelectromechanical Systems (MEMS). (4) (Same as Bioengineering CM250A and Electrical Engineer ing CM250A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Prerequisites: Chemistry 20, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to 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 device. Concurrently scheduled with course CM180. Letter grading. Mr. Chiou (F)

M280B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering and Electrical Engineering M250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Prerequisites: course CM180. 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. Letter grading. Mr. Y. Chen (Sp)

CM280L. Introduction to Micromachining and Mi croelectromechanical Systems (MEMS) Laborato ry. (2) (Same as Bioengineering CM250L and Electrical Engineering CM250L.) Lecture, one hour; labora tory, four hours; outside study, one hour. Prerequisites: course CM280A. Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micro machining technologies and microelectromechanical systems (MEMS) laboratory. Methods of microma chining and how these methods can be used to pro duce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through processes of fabrication, laboratory work, and data acquisition and analysis. Letter grading. Mr. Y. Chen (Sp)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Basic science issues in micro domain. Topics include micro fluid science, microscale heat transfer, mechanical behavior of microstructures, as well as dynamics and control of micro devices. Letter grading. Mr. Ho (W), Mr. C-J. Kim (F)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Bioengi neering M252 and Electrical Engineering M252.) Lecture, four hours; laboratory, one hour. 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 for MEMS. Design project required. Letter grading. Mr. Chiou (W)

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Prerequisites: Principles and performance of micro transducers. Applications of using unique properties of micro transducers for distributed and real-time control of engineering problems. Associated signal processing requirements for these applications. Letter grading. Mr. Ho (W)

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 application of their knowledge to engineering problems. Fundamental conceptual interface phenomena, including surface tension, surfactants, interfacial thermal energy, solvation, interfacial hydrodynam ics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, films and emulsions, as well as micromechanical and biologi cal systems. Letter grading. Mr. Pilon


M287. Nanoscience and Technology. (4) Letter grading. Mr. C-J. Kim

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 104, Physics 17. Science and engineering of laser materials for semiconductor, magnetic, electronic, optical, optical, optoelectronic, and many other applications. Letter grading. Mr. Gibson (Sp)


290. Computational Geometry for Design and Manuf acturing. (4) Lecture, four hours; outside study, eight hours. Requisites: course 184. Computational geometry for design and manufacturing, with special emphasis on curve and surface theory, geometric modeling of curves and surfaces, B-splines and NURBS, composite curves and surfaces, computer-aided design methods for surface manufacture, and current research topics in computational geometry for CAD/CAM systems. Letter grading. Mr. Ghoniem

295B. Internet-Based Collaborative Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 94, 184. Exploration of advanced state-of-the-art concepts in Internet-based collaborative design, including software environments to connect designers over Internet, networked variable media graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mobile device-based systems, and multifunctional design and manufacturing software tools to support it. Letter grading. Mr. Gadh

295C. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. Mr. Gadh

296A. Damage and Failure of Materials in Me chanical Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A. Role of failure prevention in mechanical design and case studies. Mechanics and physics of material imperfec-
296B. Thermochemical 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 transport, transpiration mechanisms of heat and mass, moving interfaces and heat sources, natural convection, nucleation and growth of microstructure, etc. Applications with chemical vapor deposition, infiltration, etc. Letter grading. 
Mr. Ghoniem (F)

Mr. Ghoniem, Ms. Lavine

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. (F,Sp)

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. 
Ms. Lavine (F,Sp)

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.

The M.S. program is addressed to those interested in developing up-to-date knowledge of cutting-edge engineering and technology.

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 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqrintro.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, signal 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.

For students who already hold an M.S. degree, a separate certificate of completion of the system engineering program can be earned by completing three of the core courses. See http://msengrol.seas.ucla.edu/areas-of-study for further information.

seas.ucla.edu
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 22.

Faculty Areas of Thesis Guidance
Professors Emeriti
Allen B. Rosenstein, Ph.D. (UCLA, 1958) Educational delivery systems, computer-aided design, design, automatic controls, magnetic controls, nonlinear electronics
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. (B) 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 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.

87. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as professional opportunity for freshmen students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team process. Investigation of osteopathy, study, seven hours. 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 members. 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 for credit with the consent of the department and dean required. P/NP grading. Mr. Wesel (F, W)

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 specifics of engineering courses to real world of engineer and roadmap of extracurricular activity that strengthens skills needed to acquire good jobs and achieve career success. P/NP grading. Mr. Silverstein (F, W)

99. Student Research Program. (1 to 2) Tutorial (supervised research of original study), 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 20A, 20B, 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, electrical and structural 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. Ozolin (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 engineered and recombined to perform desirable functions in both intracellular and cell-free environments. Fundamentals of basic technologies and systems analysis that deal with dynamic behavior, noise, and uncertainties. Design project in which students are challenged to generate new biosystems and nanosystems for non-trivial task required. Letter grading. Mr. Liao

M103. Environmental Nanotechnology: Implications and Applications. (4) (Formerly numbered 103.) Seminar/Enrollment is restricted to the Junior/ Senior level. Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: course M101. Introduction to potential implications of nanotechnology to environmental system, including application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties; (2) use of transport, reactivity, and toxicity of nanoscale materials in natural environment systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Mr. Hoek (Sp)

110. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, two hours; 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 governments make decisions related to commercialization of high technology products and services. Letter grading. Mr. Monbouquette (FSp)

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 (within business organization) and external (marketplace) financing, and marketing 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 (FW)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of entrepreneurship, venture creation, human resources, and accounting disciplines as they impact management of technology commercialization. Topics include intellectual property management, team building, market forecasting, and entrepreneurship financing. 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 (WSp)

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 follower; growth strategy, growth through acquisition, and new ventures; portfolio product management. Case studies, class projects, group discussions, and guest lectures by speakers from industry. Letter grading. Mr. Pao (W)

180. Engineering of Complex Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/seniors. Holistic view of engineering discipline, covering lifecycle of engineering, processes, and techniques used in industry today. Multidisciplinary 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 paid to link material covered to engineering curriculum offered by UCLA to help students integrate and enhance their understanding of knowledge already acquired. Motivation for and techniques continue their learning and reinforce lifelong learning habits. Letter grading. Mr. Wesel (Sp)

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. Readings address

4. Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or 3H or English as a Second Language 36. Not open for credit to students with credit for course 183EW. Designed for junior/senior engineering students. Non-technical skills and experiences necessary for engineering career success. Importance of group dynamics in engineering. Teamwork and effective group skills in engineering environments. Organization and control of multidisciplinary complex engineering projects. Forms of leadership and qualities and characteristics of effective leaders. How engineering, computer sciences, and technology relate to moral and legal issues. Societal demands on practice of engineering. Emphasis on research and writing in engineering environments. Satisfies engineering writing requirement. Letter grading.

Mr. Wesel (F.W.Sp)


Mr. Wesel (F.W.Sp)

188. Special Courses in Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in engineering for undergraduate students taught on experimental or temporary basis, such as topics taught by resident and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading.

Mr. Wesel (F.W.Sp)

195. Topics in Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to juniors/seniors. Independent research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit. Individual contract with faculty mentor and special permission required. Tutorial, four hours; outside study, eight hours. Directed Research in 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 petition available in Office of Academic and Student Affairs. Letter grading.

Mr. Wesel (F.W.Sp)

Graduate Courses

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of 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. Wesel (W)

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. Wesel (W)

202. Reliability, Maintainability, and Supportability. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 201. Designed for graduate students with one to two years work experience. Integrates scientific support (ILS) 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—leading to specialized 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.

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 project management and system engineering principles. Introduction to system architecture and its importance in project management. Limitations of current tools and systems. Discussion of selected elements of architectural practices, such as representation models, design progression, and architecture frameworks. Examination of professionalization of system architecture. Letter grading.

Mr. Wesel (F.W.Sp)

204. Trusted Systems Engineering. (4) Lecture, four hours. Placed in information systems to be properly; 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 compartmentalizing systems from network systems, computer security, data encryption, cryptography, etc. One can use most secure components, and resulting system could still be vulnerable. Skills learned ensure that systems are designed, implemented, tested, and approved for real-world use. Aspects include assessing vulnerability and risk for systems, establishing protection protocols, and using them as a guide to formulate system architectures; translating architectural design and verify correctness of design; and constructing and following trusted development and implementation process. Letter grading.

Mr. Abe, Mr. Cong, Mr. Wesel (W)

215. Entrepreneurship for Engineers. (4) Lecture, four hours. Limited to graduate engineering students. Topics in starting and developing high-tech enterprises and intended for students who wish to complement their technical education with entrepreneurship. Letter grading.

Mr. Lynch (F.W.Sp)

299. Capstone Project. (4) Activity, 10 hours. Preparation: completion of minimum of four 200-level courses in one M.S. program. Project course that satisfies UCLA final comprehensive examination requirement of M.S. online degree in Engineering, Project is completed under individual guidance from UCLA Engineering faculty members and is incorporated into advanced knowledge learned in M.S. program of study. Letter grading.

Mr. Lynch (F.W.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.


471A-471B-471C. Engineer in General Environment, (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and values for effective leadership. In Progress (471B) and S/U or letter (471C) grading.

472A-472B. Engineer in Business Environment, (3-3-1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Language of business for engineering executive. Accounting, fi-
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 customized 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 UCLA 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 2008 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 agenda that promise to define the future of computing and information and to render great benefit to society.

Center for Function Accelerated nanoMaterial Engineering
Semiconductor Research Corporation (SRC) STARnet and Defense Advanced Research Projects Agency (DARPA) Researcher Center Jane P. Chang, Ph.D. (Chemical and biomolecular Engineering), Director; http://fame-nano.org

Research at the Center for Function Accelerated nanoMaterial Engineering (FAME) aims to incorporate nonconventional materials and nanostructures with their quantum properties for enabling analog, logic, and memory devices for non-Boolean computation. Its main focus is nonconventional material solutions ranging from semiconductors, dielectrics, and metallic materials as well as their correlated quantum properties. By creating and investigating these new atomic-scale engineered materials and structures, FAME will accelerate innovations in analog, logic, and memory devices for revolutionary impact on the semiconductor and defense industries.

The center focuses on prediction, growth, and multifunctional properties of nanoscale materials and structures to address broad research needs. Its four-theme strategy allows it to focus on metals, semiconductors, spintronic materials, atomic layered materials, and proto-typing; its discovery initiative allows it to fund projects based on recent discoveries within and outside the center to accelerate applications and further its own research.

FAME is one of six university-based STARnet research centers. FAME’s multi-university partnership includes 35 faculty researchers from 16 top U.S. universities. It will receive $6 million in SRC/DARPA funding.

Center for Translational Applications of Nanoscale Multiferroic Systems
National Science Foundation Engineering Research Center
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering), Director; Jane P. Chang, Ph.D. (Chemical and biomolecular Engineering), Deputy Director; http://www.tanms.ucla.edu

Beyond development of revolutionary, miniature electromagnetic electronics by means of a new class of nanoscale multiferroic materials, the Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) seeks to increase its capacity for innovation by integrating its multidisciplinary research with commercialization and the fostering of lifelong skill development. It brings together domestic and international talents to stimulate their pursuit of engineering careers in the U.S. Its education program works with students in K-12, undergraduate, and postgraduate levels to instill a thirst for technological innovation and provide the appropriate entrepreneurial skills for long-term success in the engineering world.

TANMS seeks out the talents of individuals in every community through a compelling diversity strategy that aims at increasing participation from traditionally underrepresented groups in collaboration with source departments and schools, resulting in a diverse, inclusive environment for creative and innovative research.

Molecularly Engineered Energy Materials Energy Frontier Research Center
U.S. Department of Energy, Office of Science, Basic Energy Sciences
Vivids 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 eas-
ily assembled from intelligently designed 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](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 IP’s 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 naming 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**

Rajat Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director; [http://smart-grid.ucla.edu](http://smart-grid.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 towards 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, cyber-security, and consumer behavior.

**Western Institute of Nanoelectronics**

*Nanoelectronics Research Initiative National Institute of Excellence*

Kang L. Wang, Ph.D. (Electrical Engineering), Director; [http://win-nano.org](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-generation 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 corralling electrons into one smooth chain of motion.

**Wireless Health Institute**

Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical Engineering), Majid Sarrafzadeh, Ph.D. (Computer Science), Co-Directors; [http://www.wireless-health.ucla.edu](http://www.wireless-health.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 Translational 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

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<tr>
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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/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 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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#### SOPHOMORE YEAR

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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics</td>
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#### JUNIOR YEAR

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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 182A — Mathematics of Engineering</td>
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<td>Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics</td>
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<td>Mechanical and Aerospace Engineering 157S — Basic Aerospace Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 150B — Aerodynamics</td>
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<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems</td>
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<td>Mechanical and Aerospace Engineering 150R (Rocket Propulsion Systems)** or Aerospace Engineering Elective†</td>
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#### SENIOR YEAR

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<tr>
<td>1st</td>
<td>Mechanical and Aerospace Engineering 151P — Aircraft Propulsion Systems</td>
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<td>Mechanical and Aerospace Engineering 154S — Flight Mechanics, Stability, and Control of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 161A (Introduction to Astronautics)** or Aerospace Engineering Elective†</td>
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<td>Mechanical and Aerospace Engineering 166A — Analysis of Flight Structures</td>
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<td>Mechanical and Aerospace Engineering 154A — Preliminary Design of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 154B — Design of Aerospace Structures</td>
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<td>Mechanical and Aerospace Engineering 157A — Fluid Mechanics and Aerodynamics Laboratory</td>
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**A total of 8 units of aerospace engineering electives (two courses) is required.

** Either Mechanical and Aerospace Engineering 150R or 161A is required.

*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 Bioengineering Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<td>Bioengineering 10 — Introduction to Bioengineering</td>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</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>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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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory II</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Bioengineering 100 — Bioengineering Fundamentals</td>
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<td>Bioengineering 167L — Bioengineering Laboratory</td>
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<td>Bioengineering 165EW** — Bioengineering Ethics</td>
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<td>Life Sciences 23L — Introduction to Laboratory and Scientific Methodology</td>
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<td>Bioengineering 176 — Principles of Biocompatibility</td>
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<td>Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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<td>Bioengineering C106 — Topics in Biophysics, Channels, and Membranes</td>
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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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**TOTAL** 187

* 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, C170, C171, CM178, C179, 180L, 181, 181L, 199 (6 units maximum).
## B.S. in Chemical Engineering Curriculum

### FRESHMAN YEAR

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# B.S. in Chemical Engineering
## Biomolecular Engineering Option Curriculum

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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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### Senior Year

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<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>2nd</td>
<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>HSSEAS GE Elective*</td>
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<td></td>
<td>Technical Breadth Course*</td>
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<tr>
<td>3rd</td>
<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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**Total**: 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).*
## B.S. in Chemical Engineering

### Semiconductor Manufacturing 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 — Chemical Energetics and Change</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>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry I: Structure and Reactivity</td>
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<td>Mathematics 32A — Calculus of Several Variables</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 30B — Organic Chemistry I: Structure and Reactivity</td>
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<td>Mathematics 33A — Linear Algebra and Applications</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>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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### SENIOR YEAR

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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>3rd</td>
<td>Chemical Engineering 104C/104CL — Semiconductor Processing/Laboratory</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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<td>Chemical Engineering 1116 — Surface and Interface Engineering</td>
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**TOTAL 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).
# B.S. in Civil Engineering Curriculum

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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Civil and Environmental Engineering 1 — Introduction to Civil Engineering</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Civil and Environmental Engineering 101 — Statics and Dynamics</td>
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<td>Civil and Environmental Engineering 103 — Applied Numerical Computing and Modeling in Civil and Environmental Engineering</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics</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>Civil and Environmental Engineering 110 — Introduction to Probability and Statistics for Engineers</td>
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<td>Major Field Electives (2)†</td>
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**TOTAL**: 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 pages 45–46.
# B.S. in Computer Science Curriculum

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<tr>
<td>Computer Science 1 — Freshman Computer Science Seminar</td>
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<td>Computer Science 31 — Introduction to Computer Science I</td>
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<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<tr>
<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Computer Science 33 — Introduction to Computer Organization</td>
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<tr>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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**SOPHOMORE YEAR**

| **1st Quarter** | |
| Computer Science 35L — Software Construction Laboratory | 2 |
| Computer Science M51A or Electrical Engineering M16 — Logic Design of Digital Systems | 4 |
| Mathematics 32B — Calculus of Several Variables | 4 |
| Physics 4BL — Electricity and Magnetism Laboratory | 2 |
| **2nd Quarter** | |
| Mathematics 33A — Linear Algebra and Applications | 4 |
| Mathematics 61 — Introduction to Discrete Structures | 4 |
| Physics 1C — Electrodynamics, Optics, and Special Relativity | 5 |
| HSSEAS Ethics Course | 4 |
| **3rd Quarter** | |
| Computer Science 111 — Operating Systems Principles | 5 |
| Computer Science M152A or Electrical Engineering M116L — Introductory Digital Design Laboratory | 2 |
| Mathematics 33B — Differential Equations | 4 |
| HSSEAS GE Elective* | 5 |

**JUNIOR YEAR**

| **1st Quarter** | |
| Computer Science 118 — Computer Network Fundamentals | 4 |
| Computer Science 180 — Introduction to Algorithms and Complexity | 4 |
| HSSEAS GE Elective* | 4 |
| Science and Technology Elective | 4 |
| **2nd Quarter** | |
| Computer Science 131 — Programming Languages | 4 |
| Computer Science M151B or Electrical Engineering M116C — Computer Systems Architecture | 4 |
| Statistics 100A — Introduction to Probability | 4 |
| HSSEAS GE Elective* | 5 |
| **3rd Quarter** | |
| Computer Science 181 — Introduction to Formal Languages and Automata Theory | 4 |
| Computer Science Elective | 4 |
| HSSEAS GE Elective* | 5 |
| Technical Breadth Course* | 4 |

**SENIOR YEAR**

| **1st Quarter** | |
| Computer Science 130 (Software Engineering) or 152B (Digital Design Project Laboratory) | 4 |
| Computer Science Elective | 4 |
| HSSEAS GE Elective* | 4 |
| Science and Technology Elective | 4 |
| **2nd Quarter** | |
| Computer Science Electives (2) | 8 |
| Technical Breadth Course* | 4 |
| **3rd Quarter** | |
| Computer Science Elective | 4 |
| Science and Technology Elective | 4 |
| Technical Breadth Course* | 4 |

**TOTAL**

183

* 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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<td>Physics 4AL — Mechanics Laboratory</td>
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<tr>
<td>Computer Science 35L — Software Construction Laboratory</td>
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<td>Mathematics 61 — Introduction to Discrete Structures</td>
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<td>Computer Science 111 — Operating Systems Principles</td>
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<td>Statistics 100A — Introduction to Probability</td>
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<td>Computer Science 118 — Computer Network Fundamentals</td>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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</table>

| 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).
# B.S. in Electrical Engineering Curriculum

### FRESHMAN YEAR

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<td>Computer Science 52 — Introduction to Computer Science II</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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<td>Electrical Engineering 103 — Applied Numerical Computing</td>
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<td>Mathematics 33C — Complex Analysis for Applications</td>
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### JUNIOR YEAR

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<td>Electrical Engineering 101B — Electromagnetic Waves</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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<td>Electrical Engineering 115AL — Analog Electronics Laboratory I</td>
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<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
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<td>Electrical Engineering 132A — Introduction to Communication Systems</td>
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<td>Electrical Engineering 141 — Principles of Feedback Control</td>
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### SENIOR YEAR

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**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 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>Mathematics 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory II</td>
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### SOPHOMORE YEAR

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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>Life Sciences 3 — Introduction to Molecular Biology</td>
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### JUNIOR YEAR

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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Electrical Engineering 101A — Engineering Electromagnetics</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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<td>Pathway Course (Electrical Engineering 141 — Principles of Feedback Control)†</td>
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### SENIOR YEAR

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<td>2nd Quarter</td>
<td>Mathematics 132 — Complex Analysis for Applications</td>
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<td>Pathway Course (Electrical Engineering Thermodynamics)†</td>
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**TOTAL 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).
† See page 74 for the biomedical engineering pathway.
B.S. in Electrical Engineering

Computer Engineering Option Curriculum

FRESHMAN YEAR

1st Quarter
Computer Science 31 — Introduction to Computer Science I .................................................. 4
English Composition 3 — English Composition, Rhetoric, and Language .......................... 5
Mathematics 31A — Differential and Integral Calculus ......................................................... 4

2nd Quarter
Chemistry and Biochemistry 20A — Chemical Structure ..................................................... 4
Computer Science 32 — Introduction to Computer Science II ............................................... 4
Mathematics 31B — Integration and Infinite Series ................................................................. 4
Physics 1A — Mechanics ......................................................................................................... 5

3rd Quarter
Computer Science 33 — Introduction to Computer Organization ........................................... 5
Mathematics 32A — Calculus of Several Variables ................................................................. 4
Physics 1B — Oscillations, Waves, Electric and Magnetic Fields ......................................... 5
HSSEAS GE Elective* ............................................................................................................. 5

SOPHOMORE YEAR

1st Quarter
Electrical Engineering 3 — Introduction to Electrical Engineering ...................................... 3
Mathematics 32B — Calculus of Several Variables ................................................................. 4
Physics 4AL — Mechanics Laboratory .................................................................................... 2

2nd Quarter
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
Physics 1C — Electrodynamics, Optics, and Special Relativity ........................................... 5

3rd Quarter
Electrical Engineering 102 — Systems and Signals .............................................................. 4
Mathematics 33C — Complex Analysis for Applications ..................................................... 4
Physics 4BL — Electricity and Magnetism Laboratory ............................................................ 2
HSSEAS Ethics Course ........................................................................................................... 4

JUNIOR YEAR

1st Quarter
Computer Science 3SL — Software Construction Laboratory .............................................. 2
Electrical Engineering 101A — 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 103 — Applied Numerical Computing ............................................ 4
Electrical Engineering 115C — Digital Electronic Circuits .................................................... 4
HSSEAS GE Elective* ............................................................................................................. 4
Pathway Course (Electrical Engineering 132A — Introduction to Communication Systems or Computer Science 117 — Computer Networks: Physical Layer†) ......................................................... 4

SENIOR YEAR

1st Quarter
HSSEAS GE Elective* ............................................................................................................. 5
Pathway Course (Computer Science 111 — Operating Systems Principles)† ......................... 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 131 — Programming Languages or 132 — Compiler Construction or 180 — Introduction to Algorithms and Complexity)† ............................................. 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 ...................................................................................................................................... 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).
† See page 73 for the computer engineering pathway.
## B.S. in Materials Engineering Curriculum

### FRESHMAN YEAR

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<td>Materials Science and Engineering 10 — Freshman Seminar: New Materials</td>
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<td>Physics 1A — Mechanics</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>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Materials Science and Engineering 90L — Physical Measurements in Materials Engineering</td>
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<td>Mathematics 33B — Differential Equations</td>
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### JUNIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<tr>
<td></td>
<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 130 — Phase Relations in Solids</td>
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<td>2nd</td>
<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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<td>Materials Engineering Electives (2)*</td>
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### SENIOR YEAR

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<tr>
<td>1st</td>
<td>Materials Science and Engineering 160 — Introduction to Ceramics and Glasses</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 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

<table>
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<tr>
<th>Quarter</th>
<th>Course Title</th>
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<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<tr>
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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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<tr>
<td>3rd</td>
<td>Computer Science 31 — Introduction to Computer Science I</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>
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<tbody>
<tr>
<td>1st</td>
<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>HSSEAS GE Elective*</td>
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<tr>
<td>2nd</td>
<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td>3rd</td>
<td>Materials Science and Engineering 90L — Physical Measurement in Materials Engineering</td>
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<td>Mathematics 33B — Differential Equations</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials</td>
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<td>HSSEAS Ethics Course</td>
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### JUNIOR YEAR

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<th>Course Title</th>
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<tbody>
<tr>
<td>1st</td>
<td>Electrical Engineering 10 — Circuit Theory I</td>
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<td>Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Laboratory</td>
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<tr>
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<td>Materials Science and Engineering 130 — Phase Relations in Solids</td>
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<tr>
<td>2nd</td>
<td>Electrical Engineering 101A — 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>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</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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### SENIOR YEAR

<table>
<thead>
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<th>Quarter</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Mechanical and Aerospace Engineering 181A (Complex Analysis and Integral Transforms) or 182A (Mathematics of Engineering)</td>
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<td>Electronic Materials Elective†</td>
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<td>Technical Breadth Course*</td>
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<td>3rd</td>
<td>Materials Science and Engineering 140 — Materials Selection and Engineering Design</td>
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### TOTAL

188

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† See counselor in 6426 Boelter Hall for details.
# B.S. in Mechanical Engineering Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<tr>
<td>Mathematics 31A — Differential and Integral Calculus</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
<td>Physics 1A — Mechanics</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Computer Science 31 — Introduction to Computer Science</td>
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</tr>
<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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<td>Physics 4AL — Mechanics Laboratory</td>
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<th>SOPHOMORE YEAR</th>
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<tr>
<td>Mathematics 32B — Calculus of Several Variables</td>
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<tr>
<td>Mechanical and Aerospace Engineering 94 — Introduction to Computer-Aided Design and Drafting</td>
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<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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<tr>
<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<tr>
<td>Mathematics 33A — Linear Algebra and Applications</td>
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</tr>
<tr>
<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials</td>
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<tr>
<td>Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Mathematics 33B — Differential Equations</td>
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<tr>
<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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<tbody>
<tr>
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<tr>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<tr>
<td>Mechanical and Aerospace Engineering 105D — Transport Phenomena</td>
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<tr>
<td>Mechanical and Aerospace Engineering 162A — Introduction to Mechanisms and Mechanical Systems</td>
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<tr>
<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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<tr>
<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 and Aerospace Engineering 171A — Introduction to Feedback and Control Systems</td>
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<td>Mechanical and Aerospace Engineering 162D — Mechanical Engineering Design I</td>
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**TOTAL**: 185

* 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).
### Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2013</th>
<th>Winter 2014</th>
<th>Spring 2014</th>
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</thead>
<tbody>
<tr>
<td>First day for continuing students to check URSA at</td>
<td>June 5</td>
<td>October 30</td>
<td>January 29, 2014</td>
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<tr>
<td><a href="http://www.ursa.ucla.edu">http://www.ursa.ucla.edu</a> for assigned enrollment appointments</td>
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<tr>
<td>URSA enrollment appointments begin</td>
<td>June 17</td>
<td>November 12</td>
<td>February 10</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 23</td>
<td>January 2, 2014</td>
<td>March 26</td>
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<tr>
<td>Instruction begins</td>
<td>September 26</td>
<td>January 6</td>
<td>March 31</td>
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<tr>
<td>Last day for undergraduates to ADD courses with per-course fee through URSA</td>
<td>October 18</td>
<td>January 24</td>
<td>April 18</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 25</td>
<td>January 31</td>
<td>April 25</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 8</td>
<td>February 14</td>
<td>May 9</td>
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<tr>
<td>Instruction ends</td>
<td>December 6</td>
<td>March 14</td>
<td>June 6</td>
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<tr>
<td>Final examinations</td>
<td>December 9-13</td>
<td>March 17-21</td>
<td>June 9-13</td>
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<td>QUARTER ENDS</td>
<td>December 13</td>
<td>March 21</td>
<td>June 13</td>
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<td>June 14</td>
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<td>Academic and administrative holidays</td>
<td>November 11</td>
<td>January 20</td>
<td>March 28</td>
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<td>November 28-29</td>
<td>February 17</td>
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<td>December 24-25</td>
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<td></td>
<td>January 1</td>
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<tr>
<td>Winter campus closure</td>
<td>December 23, 26,27, 30</td>
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### Admission Calendar

<table>
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<th>Winter 2014</th>
<th>Spring 2014</th>
</tr>
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<tbody>
<tr>
<td>Filing period for undergraduate applications (file with UC</td>
<td>November 1-30,</td>
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<tr>
<td>Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)</td>
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<td>Last day to file Application for Graduate Admission or</td>
<td>Consult</td>
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<td>department</td>
<td>department</td>
<td>department</td>
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<tr>
<td>with Graduate Diversity, Inclusion, and Admissions (DIA), 1248 Murphy Hall, UCLA, Los Angeles, CA 90024-1419</td>
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<tr>
<td>Last day to file Undergraduate Application for Readmission</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
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<tr>
<td>form at 1113 Murphy Hall (late applicants pay a late fee)</td>
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