ANNOUNCEMENT
OCTOBER 1, 2010

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

Our faculty members and students are leaders in new frontiers of applied science and engineering research, in areas such as clean and renewable energy, clean water technology, 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 curriculumó with its emphasis on breadth of knowledge as well as depthó 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 schoolís world-class interdisciplinary research centers. These include the NSF Center for Embedded Networked Sensing, NIH Center for Cell Control, Center on Functional Engineered Nano Architectonics, NRI Western Institute of Nanoelectronics, DOE-funded Center for Molecularly Engineered Energy Materials, and NSF Center for Domain-Specific Computing. 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.

Our distinguished faculty is composed of recognized experts in their fields, including 20 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.

We are 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
DISCLOSURE OF STUDENT RECORDS

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 request to amend the records or, if such request is denied, through a hearing, and (5) file complaints with the U.S. Department of Education regarding alleged violations of the rights accorded them by FERPA.

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

Students who do not wish certain items (i.e., name, local/mailing, permanent, and/or e-mail address, telephone numbers, major field of study, dates of attendance, number of course units in which enrolled, and degrees and honors received) of this “directory information” released and published may so indicate through URSA (http://www.ursa.ucla.edu). To restrict the release and publication of the additional items in the category of “directory information,” complete the UCLA FERPA Restriction Request form available from the Registrar’s Office, 1113 Murphy Hall.

Student records that are the subject of Federal and State Laws and University Policies may be maintained in a variety of offices, including the Registrar’s Office, Office of the Dean of Students, UCLA Career Center, Graduate Division, and the offices of a student’s College or school and major department. Students are referred to the UCLA Telephone Directory (http://www.directory.ucla.edu) which lists all the offices that may maintain student records, together with their campus address and telephone number. Students have the right to inspect their student records in any such office subject to the terms of Federal and State Laws and University Policies. Inspection of student records maintained by the Registrar’s Office is by appointment only and must be arranged three working days in advance. Call (310) 825-1091, option 6, or inquire at the Registrar’s Office, 1113 Murphy Hall.

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

All announcements herein are subject to revision. Every effort has been made to ensure the accuracy of the information presented in the Announcement of the UCLA Henry Samueli School of Engineering and Applied Science. However, all courses, 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://www.gdnet.ucla.edu.
The University

UCLA is recognized as the Westís 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 universityís 419-acre campus houses the College of Letters and Science and 11 professional schools. There are more than 39,984 students enrolled in 126 undergraduate and 197 graduate degree programs. Nearly one in every 140 Californians holds a UCLA degree.

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

Southern California has grown to become one of the nationís dominant industrial centers, and the UCLA Henry Samuel 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 Samuel School of Engineering and Applied Science in 2000. The school ranks among the top 10 engineering schools in public universities nationwide.

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Center for Embedded Networked Sensing (CENS) develops embedded networked sensing systems and applies this revolutionary technology to critical scientific and social applications. The Center for Cell Control (CCC) applies advanced engineering techniques and life sciences knowledge to control and understand how the cell works at the most basic level, with the goal of improving human health. The Center on Functional Nanoarchitectonics (FENA) leverages the latest advances in nanotechnology, molecular electronics, and quantum computing to extend semiconductor technology further into the realm of the nanoscale. The Energy Frontier Research Center (EFRC) focuses on the creation and production of nanoscale materials for use in converting solar energy into electricity, electrical energy storage, and capturing and separating greenhouse gases. The Western Institute of Nanoelectronics (WIN), among the worldís 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 is developing high-performance, energy efficient, customizable computing that could revolutionize the way computers are used in healthcare and other important applications. Finally, the California Nanosystems Institute (CNSI)ó a joint endeavor with UC Santa Barbaraó develops the information, biomedical, and manufacturing technologies of the twenty-first century.

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

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

The school offers 29 academic and professional degree programs, including an interdepartmental graduate degree program in biomedical engineering. 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, Biomedical Engineering, 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 was approved in June 2006. The Engineer degree is a more advanced degree than the M.S. but does not require the research effort and orientation involved in a Ph.D. dissertation. For information on the Engineer degree, see Graduate Programs on page 23. A one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science.

**Endowed Chairs**

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

- L.M.K. Boelter Chair in Engineering
- Roy and Carol Dounani Chair in Biomedical Engineering
- Norman E. Friedmann Chair in Knowledge Sciences
- Evalyn Knight Chair in Engineering
- Levi James Knight, Jr., Chair in 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
- Symantec Chair in Computer Science
- Carol and Lawrence E. Tannas, Jr., Endowed Chair in Engineering
- UCLA Engineering Endowed Chair in Civil Engineering
- 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, aeroelasticity, performance analysis, and propulsion and controls technology.

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

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

**Bioengineering**

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

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

Chemical and Biomolecular Engineering

Chemical and biomolecular engineers use their knowledge of mathematics, physics, chemistry, biology, and engineering to meet the needs of our technological society. They design, research, develop, operate, and manage within the biochemical and chemical industries and are leaders in the fields of energy and the environment, nanotechnology, systems engineering, biotechnology and biomolecular engineering, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, biotechnology, food, paper, aerospace, automotive, water production and 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 reaction processes and reactors, including combustion systems,

2. Transport phenomena, which involves the exchange of momentum, heat, and mass across interfaces 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 both separation processes and chemical reactor design, and

4. Plant and process design, synthesis, optimization, simulation, and control, which provide the overall framework 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 the aerospace industry for assignments based on their structural engineering background. Graduates are also qualified for positions outside engineering where their broad engineering education is a valuable asset.

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

Computer Science and Engineering

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

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

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

Electrical Engineering

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

Manufacturing Engineering

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

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

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

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

Materials Engineering

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

Two programs within materials engineering are available at UCLA:

1. In the materials engineering program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries. Materials engineers are responsible for the selection and testing of materials for specific applications. Traditional fields of 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
Mechanical Engineering
Mechanical engineering is a broad discipline finding application in virtually all industries and manufactured products. The mechanical engineer applies principles of mechanics, dynamics, and energy transfer to the design, analysis, testing, and manufacture of consumer and industrial products. A mechanical engineer usually has specialized knowledge in areas such as design, materials, fluid dynamics, solid mechanics, heat transfer, thermodynamics, dynamics, control systems, manufacturing methods, and human factors. Applications of mechanical engineering include design of machines used in the manufacturing and processing industries, mechanical components of electronic and data processing equipment, engines and power-generating equipment, components and vehicles for land, sea, air, and space, and artificial components for the human body. Mechanical engineers are employed throughout the engineering community as individual consultants in small firms providing specialized products or services, as designers and managers in large corporations, and as public officials in government agencies.

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

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

Teaching and research facilities at HSSEAS are in Boelter Hall, Engineering I, Engineering IV, and Engineering V, located in the southern part of the UCLA campus. Boelter Hall houses classrooms and laboratories for 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 8 million volumes, and nearly 80,000 serial titles are received regularly. Some 15,000 serials and databases are electronically available, and the UCLA Library Catalog is linked to the library's homepage at http://www.library.ucla.edu.

Science and Engineering Library
The SEL/Engineering and Mathematical Sciences Collection in Boelter Hall houses the engineering, mathematics, statistics, astronomy, and atmospheric and oceanic sciences collections, as well as most librarians and staff offices, and the administrative, collection development, and public services divisions. In addition, the library provides laptop checkout, two group study rooms, a presentation rehearsal studio, and a research commons for collaborative projects.

The SEL/Chemistry collection in Young Hall contains complementary materials in chemistry and physics. Although this collection is closed to the public, its materials can be requested in person at the Geology-Geophysics Collection. The SEL/Geology-Geophysics Collection, located at 4697 Geology Building, focuses on earth and space sciences with materials in geochemistry, geology, hydrology, tectonics, water resources, geophysics, and space physics.

The SEL collection contains over 585,000 print volumes, subscribes to almost 4,900 current serials in print and/or electronic formats, and includes over 4 million technical reports. In addition to e-journals, the library provides Web access to article databases covering each discipline and several thousand e-books.

Faculty, students, and staff can e-mail questions to the library at sel-ref@library.ucla.edu. In addition, online live chat and in-person reference assistance is provided Monday through Friday. To contact a librarian, use one of the "I" Question! links on any library webpage. 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, and 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 120 Sun Fire and Enterprise servers, Dell PowerEdge Windows servers, Network Appliance RAID NFS servers, and Linux RAID NFS servers connected to a high-speed backbone network. The machines function as cycle, file, and application servers to approximately 630 Unix and Microsoft Windows workstations for administrative and instructional support. Four open computer laboratories and one classroom for computerized instruction house 210 PC workstations and a smaller Linux laboratory. Remote access to HSSEAS coursework applications is provided via Microsoft Terminal Server.

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

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

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

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

Continuing Education

UCLA Extension
Department of Engineering, Information Systems, and Technical Management

Varaz Shahnazarian, Ph.D., Director
William R. Goodin, Ph.D., Associate Director
The UCLA Extension (UNEX) Department of Engineering, Information Systems, and Technical Management (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 five-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 80th offering in September 2010 and 81st in March 2011. See https://www.uclaextension.edu/tmp/.

The Information Systems program offers over 100 courses annually in systems analysis, applications programming, database
management, Linux/unix, operating systems, and web technology.

The engineering program offers over 200 courses annually, including 10 certificate programs in astronautical engineering, construction management, communication systems, digital signal processing, manufacturing engineering, project management, contract management, government cost estimating and pricing, supply chain management, and recycling and solid waste management. In addition, the department offers EIT and PE review courses in mechanical, civil, and chemical engineering. Most engineering and technical management courses are offered evenings on the UCLA campus, or are available online. See https://www.uclaextension.edu/eistm/.

Career Services

The UCLA Career Center assists HSSEAS undergraduate and graduate students and alumni in exploring career possibilities, preparing for graduate and professional school, obtaining employment and internship leads, and developing skills for conducting a successful job search.

Services include career consulting and counseling, skills assessments, workshops, employer information sessions, and a multimedia collection of career planning and job search resources. Bruinview offers undergraduate and graduate students with opportunities to meet one-on-one with employers seeking entry-level job candidates and offers 24-hour access to thousands of current full-time, part-time, seasonal, and internship positions. Annual career fairs for HSSEAS students are held in Fall and Winter quarters, and HSSEAS students are also welcomed at all Career Center-sponsored job fairs.

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

Arthur Ashe Student Health and Wellness Center

The Arthur Ashe Student Health and Wellness Center is a full-service medical clinic available to all registered UCLA students. Its clinical staff of physicians, nurse practitioners, and nurses is board-certified. It offers primary care, specialty clinics, and physical and occupational therapy. The center has its own pharmacy, optometry, radiology, and laboratory. Visit, core laboratory test, and X-ray fees are all no-charge for students with the UCLA Student Health Insurance Plan (SHIP). Students with SHIP pay lower co-pays for prescriptions filled at the Ashe Center pharmacy. The plan year deductible is waived for network provider office visits, diagnostic X-rays, lab, CT, MRI, and payable emergency room facility fees. The deductible applies to all other services, including at the Ashe Center acupuncture, casts, devices, immunizations, injections, urgent care facility, and physical and occupational therapy. All fees incurred at the Ashe Center are billed directly to students’ BAR 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 SHIP withdraws with less than 100% refund, SHIP 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 SHIP 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 SHIP must have follow-up visits, after emergencies, in the Ashe Center. If care cannot be provided in the Ashe Center, the Ashe Center clinician will give the student a written referral to a network provider.

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

Office hours during the academic year are weekdays 8 a.m. to 6:30 p.m. except Friday, when service begins at 9 a.m.

Located at 221 Westwood Plaza (next to John Wooden Center), (310) 825-4073; see http://www.studenthealth.ucla.edu.

Services for Students with Disabilities

The Office for Students with Disabilities (OSD) provides a wide range of academic support services to regularly enrolled students with documented permanent or temporary disabilities in compliance with Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, and University policies. Academic support services are determined for each student based on specific disability-based requirements. Services include campus orientation and accessibility, note takers, readers, 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 assistance, referral to UCLA’s Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations. There is no fee for any of these services. All contacts and assistance are handled confidentially. Located at A255 Murphy Hall; voice (310) 825-1501, TDD (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 International Hall; see http://www.internationalcenter.ucla.edu.

Fees and Financial Support

Fees and Expenses

The 2010-11 annual UCLA student fees listed below 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.
### 2010-11 ANNUAL UCLA GRADUATE AND UNDERGRADUATE FEES

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<th>Graduate Students</th>
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<td>Resident</td>
<td>Nonresident</td>
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<td>and Resources Complex Fee</td>
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<td>$11,867.94</td>
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|                                | $34,746.94        |

### Financial Aid

#### Undergraduate Students

Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. Applications for each academic year are available in January. The priority application deadline for financial aid for the 2011-12 academic year is March 2, 2011. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA). International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

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

#### Scholarships

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

### Living Accommodations

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

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

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

### Regents Scholarships

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. Need is determined according to financial aid criteria legislated by Congress.

### HSEAS Scholarships

HSEAS 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 2009-10, HSEAS awarded more than $75 undergraduate scholarship awards totaling more than $125,000. The majority of these scholarships are publicized in the Fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see http://seasoasa.ucla.edu/student-opportunities/scholarships-for-undergraduates.

### Grants

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

### Federal Pell Grants

Federal Pell Grants are federal aid awards designed to provide financial assistance to those who need funds to attend post-high school educational institutions. Undergraduate students who are U.S. citizens or eligible noncitizens are required by the University to apply.


### Federal Family Education Loan Program

Federal loans are available to undergraduate or graduate students who are U.S. citizens or eligible noncitizens and who are carrying 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.
When graduating, transferring, withdrawing, or taking a leave of absence, UCLA students who have received campus-based loans must complete an exit interview with Student Loan Services. The exit interview is provided to help students better understand 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 the Student Loan Services Office, 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 hourly wage and the employer contributes 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 financial aid application is required.

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 of up to $5,000 while at the same time reducing their Perkins and/or Stafford loan by the amount of the increase. 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 2008-09 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. Continuing graduate students should contact the Financial Aid Office in December 2008 for information on 2009-10 application procedures.

International graduate students are not eligible for need-based University financial aid nor for long-term student loans.

School of Engineering Fellowships
Fellowship packages offered by HSSEAS may include fellowship contributions from the following sources:

1. AT&T Fellowships. Supports doctoral study in electrical engineering; must be U.S. citizen or permanent resident; optional summer research at AT&T.
2. Atlantic Richfield Company (ARCO) Fellowship. Department of Chemical and Biomolecular Engineering; supports study in chemical engineering.
3. William and Mary Beadle Fellowship. Department of Chemical Biomolecular Engineering; supports study in chemical engineering.
5. Leon and Alyne Camp Fellowship. Department of Mechanical and Aerospace Engineering; supports study in engineering; must be U.S. citizen.
6. Eugene V. Cota-Robles Fellowship. Department of Mechanical and Aerospace Engineering; supports doctoral students.
7. Deutsch Company Fellowship. Supports engineering research on problems that aid small businesses in Southern California.
8. IBM Doctoral Fellowship. Supports doctoral study in computer science.
9. Intel Fellowship. Department of Computer Science; supports doctoral study in selected areas of computer science.
10. Intel Fellowship. Department of Mechanical and Aerospace Engineering; supports doctoral students.
11. Les Knesel Scholarship Fund. Department of Materials Science and Engineering; supports master’s or doctoral students in ceramic engineering.
12. T.H. Lin Graduate Fellowship. Department of Civil and Environmental Engineering; supports study in the area of structures.
13. Microsoft Fellowship. Supports doctoral study in computer science.
14. 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.
15. NCR Fellowship. Department of Computer Science; supports doctoral study in computer science.
16. Martin Rubin Scholarship. Supports two undergraduate or graduate students pursuing a degree in civil engineering.
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.

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 each school site, 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 early 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 876 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.

STEP-UP. Funded by the National Science Foundation, STEP for Underutilized Populations (STEP-UP) is a regional initiative designed to increase the number of students from Los Angeles urban core populations obtaining baccalaureate degrees in science, technology, engineering, and mathematics (STEM). Awarded in Fall 2004, this five-year, $1.8 million inter-institutional and multi-disciplinary initiative is led by the UCLA Center for Excellence in Engineering and Diversity in the Henry Samueli School of Engineering and Applied Science. Regional partners include California State University, Los Angeles (CSULA) and a number of community colleges in the Los Angeles metropolitan area. The U.S. production of domestic engineers and physical scientists has declined since the high point of the mid-1980s, while that of other countries has increased dramatically. The fastest-growing segments of the U.S. population need to be prepared to enter these vital fields.

Nearly 82 percent of the 740,000 K-12 students in the Los Angeles Unified School District are African-American and Latino, yet a minuscule number of these students attempt post-secondary STEM fields, and fewer enroll in and complete degrees in these areas. The UCLA STEP-UP project provides academic learning communities and career-oriented intervention programs to improve access, counseling, and preparation for students with high interest in these subjects. The NSF has funded over 30 STEP projects across the country to address the growing imbalance between the need for technical talent and the U.S. production of engineers and computer and physical scientists. The NSF goal is to strengthen national and economic security by increasing the number of engineers from populations that under-participate in these fields.

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

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

American Indian Science and Engineering Society
Entering its 20th year on campus, 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 study, 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.uclasoles.com.

Women in Engineering
Women make up about 19 percent of the undergraduate and 18 percent of HSSEAS 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 male-only field. Women engineers are in great demand in all fields of engineering.
Society of Women Engineers
The Society of Women Engineers (SWE), recognizing that women in engineering are still a minority, has established a UCLA student chapter that sponsors field trips and engineering-related speakers (often professional women) to introduce the various options available to women engineers. The UCLA chapter of SWE, in conjunction with other Los Angeles schools, also publishes an annual résumé book to help women students find jobs and presents a career day for women high school students. See http://www.seas.ucla.edu/swe.

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

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AIAA</td>
<td>American Institute of Aeronautics and Astronautics</td>
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<tr>
<td>AICHE</td>
<td>American Institute of Chemical Engineers</td>
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<tr>
<td>AISES</td>
<td>American Indian Science and Engineering Society</td>
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<td>ASCOE</td>
<td>American Society of Civil Engineers</td>
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<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
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<td>BMES</td>
<td>Biomedical Engineering Society</td>
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<td>CSGSC</td>
<td>Computer Science Graduate Student Committee</td>
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<tr>
<td>Eta Kappa Nu</td>
<td>Electrical engineering honor society</td>
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<tr>
<td>EWB</td>
<td>Engineers Without Borders</td>
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<tr>
<td>FEED</td>
<td>Forum for Energy Economics and Development</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<tr>
<td>ISPE</td>
<td>International Society for Pharmaceutical Engineering</td>
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<tr>
<td>LUG</td>
<td>Linux Users Group</td>
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<tr>
<td>MRS</td>
<td>Materials Research Society</td>
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<tr>
<td>NSBE</td>
<td>National Society of Black Engineers</td>
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<tr>
<td>Phi Sigma Rho</td>
<td>Engineering social sorority</td>
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<td>PIE</td>
<td>Pilipinos in Engineering Robotics Club</td>
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<td>Society of Automotive Engineers</td>
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<td>SOLES</td>
<td>Society of Latino Engineers and Scientists</td>
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<td>SWE</td>
<td>Society of Women Engineers</td>
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<tr>
<td>Tau Beta Pi</td>
<td>Engineering honor society</td>
</tr>
<tr>
<td>Triangle</td>
<td>Social fraternity of engineers, architects, and scientists</td>
</tr>
<tr>
<td>Upsilon Pi Epsilon</td>
<td>International honor society for the computing and information disciplines</td>
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</table>

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

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

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

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

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

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

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

Minimum qualifications include the completion of 24 courses (96 quarter units) at UCLA, or the equivalent at a similar institution, the current minimum grade-point average required for honors at graduation, and the requirements in preparation for the major. To obtain both the bachelor’s and master’s degrees, Departmental Scholars fulfill the requirements for each program. Students may not use any one course to fulfill requirements for both degrees.

For details, consult the Office of Academic and Student Affairs in 6426 Boelter Hall, well in advance of application dates for admission to graduate standing.

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

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

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

Grade Disputes

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

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

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

Nondiscrimination

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

Inquiries regarding the University's student-related nondiscrimination policies may be directed to the UCLA Campus Counsel, 3149 Murphy Hall, Box 951405, Los Angeles, CA 90095-1405, (310) 825-4042.

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

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

Definitions

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

Harassment is defined as conduct that is so severe and/or pervasive, and objectively offensive, in 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 her or his race, color, national or ethnic origin, alien niche, sex, religion, age, sexual orientation, gender identity, marital status, veteran status, physical or mental disability, 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.

For both student and/or employee sexual harassment, refer to the University of California Procedures for Responding to Reports of Sexual Harassment.

Complaint Resolution

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

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

1. Campus Human Resources/Employee and Labor Relations, Manager, 200 UCLA Wilshire Center, (310) 794-0860
2. Campus Human Resources/Staff and Faculty Counseling Center, Coordinator, 380 UCLA Wilshire Center, (310) 794-0248
3. Center for Student Programming, Associate Director, 105 Kerckhoff Hall, (310) 206-8817
4. Chancellor's Office, Sexual Harassment Coordinator, 2241 Murphy Hall, (310) 206-3417
5. Counseling and Psychological Services, Director, 221 Wooden Center West, (310) 825-0768
6. David Geffen School of Medicine, Dean's Office, Special Projects Director, 12-138 Center for the Health Sciences, (310) 794-1958
7. Graduate Division, Office Manager, 1237 Murphy Hall, (310) 206-3269
8. Healthcare Human Resources, Employee Relations Manager, 400 UCLA Wilshire Center, (310) 794-0500
9. Lesbian Gay Bisexual Transgender Campus Resource Center, Director, B36 Student Activities Center, (310) 206-3628
10. Office of the Dean of Students, Assistant Dean of Students, 1206 Murphy Hall, (310) 825-3871
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 the Universitywide Student Conduct Harassment Policy (http://www.deanofstudents.ucla.edu), students may be subject to University discipline for misconduct which may consist solely of expression. Copies of this Policy are available in the Office of the Dean of Students, 1206 Murphy Hall, or in any of the Harassment Information Centers listed below:

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

**Complaint Resolution**

One of the necessary measures in our efforts to assure an atmosphere of civility and mutual respect is the establishment of procedures which provide effective informal and formal mechanisms for those who believe that they have been victims of any of the above misconduct. Many incidents of harassment and intimidation can be effectively resolved through informal means. For example, an individual may wish to confront the alleged offender immediately and firmly. An individual who chooses not to confront the alleged offender and who wishes help, advice, or information is urged to contact any of the Harassment Information Centers listed immediately above.

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

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

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

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

The following curricula are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), the nationally recognized accrediting body for engineering programs: aerospace engineering, chemical engineering, civil engineering, computer science and engineering, electrical engineering, materials engineering, and mechanical engineering. The computer science and computer science and engineering curricula are accredited by the Computing Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

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. In addition, all applicants must complete two SAT Subject Tests in two different subject areas selected from history/social studies, mathematics (Mathematics Level 2 only), laboratory science, and a language other than English.

Applicants to the school are strongly encouraged to 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 Tests

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Tests with scores of 3, 4, or 5. Students with AP Test credit may exceed the 213-unit maximum by the amount of this credit. AP Test credit for freshmen entering Fall Quarter 2010 fulfills HSSEAS requirements as indicated on the AP chart.

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 3.2 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
All units and course equivalents to AP Tests are lower division. If an AP Test has been given UCLA course equivalency (e.g., Economics 2), it may not be repeated at UCLA for units or grade points.

<table>
<thead>
<tr>
<th>AP Test</th>
<th>Score</th>
<th>UCLA Lower Division Units and Course Equivalents</th>
<th>Credit Allowed for University and GE Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></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, or 5</td>
<td>2 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Economics 2 (4 units)</td>
<td>4 units toward social analysis GE</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Economics 1 (4 units)</td>
<td>4 units toward social analysis GE</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></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, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Course</td>
<td>Units</td>
<td>Description</td>
<td>Application</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>French Literature</td>
<td>3 or 4</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) + 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>8 units maximum for both tests</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>Latin Literature</td>
<td>3</td>
<td>Latin 1 (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>Spanish Language</td>
<td>3</td>
<td>Spanish 4 (4 units) + 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3 or 4</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td>8 units maximum for both tests</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td>8 units maximum for all tests</td>
<td>No application</td>
<td></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>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>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>
of the Electrical Engineering major require only one term of chemistry
4. Computer programming, including either Java, C, or C++. Applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors must take C++
5. Biology, including one year of biology only for applicants to the Bioengineering major
6. English composition courses, including one course equivalent to UCLAs 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.

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 185 and 190, depending on the program. The maximum allowed is 213 units.
After 213 quarter units, enrollment may not normally be continued in the school without special permission from the associate dean. This regulation does not apply to Departmental Scholars.

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

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

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

Writing I
The Writing I requirement must be satisfied by completing English Composition 3 or 3H with a grade of C or better (Cñ or a Passed grade is not acceptable) by the end of the second year of enrollment. The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement Tests in English or a combination of a score of 720 or higher on the SAT Reasoning Test Writing Section and superior performance on the English Composition 3 Proficiency Examination.
Students whose native language is not English may satisfy the Writing I requirement by completing English as a Second Language 36 with a grade of C or better (Cñ 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 (Cñ 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 (Cñ 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 and ethics 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 Biomedical Engineering 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/ge.html.
Department Requirements

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

Preparation for the Major

A major requires completion of a set of courses known as Preparation for the Major. Each department sets its own Preparation for the Major requirements; see the Departments and Programs section of this announcement.

The Major

Students must complete their major with a scholarship average of at least 2.0 (C) in all courses in order to remain in the major. Each course in the major department must be taken for a letter grade. See the Departments and Programs section of this announcement for details on each major.

Policies and Regulations

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

Student Responsibility

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

Study List

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

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

Minimum Progress

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

Credit Limitations

Advanced Placement Tests

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

College Level Examination Program

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

Community College Unit Limit

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

Foreign Language

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

Double Majors

Students in good academic standing may be permitted to have a double major consisting of a major within HSSEAS and a major outside the school (e.g., Electrical Engineering and Economics). Students are not permitted to have a double major within the school (e.g., Chemical Engineering and Civil Engineering). Contact the Office of Academic and Student Affairs for details.

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 student's 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.

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. Students following the 2005-06 catalog year and thereafter will be notified by the Office of Academic and Student Affairs of a new program called Degree Audit Reporting System (DARS). The student's regular faculty adviser is available to assist in planning electives and for discussions regarding career objectives. Students should discuss their elective plan with the adviser and obtain the adviser's approval.

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

Students are assigned to advisers by majors and major fields of interest. A specific adviser or an adviser in a particular engineering department may be requested by submitting a Request for Assignment to Faculty Adviser form available in the Office of Academic and Student Affairs.

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 require-
ments 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 Deanís 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 Deanís Honors.

**Latin Honors**

Students who have achieved scholastic distinction may be awarded the bachelorís degree with honors. Students eligible for 2010-11 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 3.871 or better) for summa cum laude, the next five percent (GPA of 3.771 or better) for magna cum laude, and the next 10 percent (GPA of 3.624 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 3.871 grade-point average for summa cum laude, a 3.771 for magna cum laude, and a 3.624 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field courses. To be eligible for an award, students should have completed at least 80 upper division units at the University of California.
Graduate Programs

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

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

Master of Science Degrees

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

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://msengrol.seas.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.

Biomedical Engineering Interdepartmental Program

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

Chemical and Biomolecular Engineering Department

Chemical engineering

Civil and Environmental Engineering Department

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

Computer Science Department

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

Electrical Engineering Department

Circuits and embedded systems
Physical and wave electronics
Signals and systems

Materials Science and Engineering Department

Ceramics and ceramic processing
Electronic and optical materials
Structural materials

Mechanical and Aerospace Engineering Department

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

Admission
Applications for admission are invited from graduates of recognized colleges and universities. Selection is based on promise of success in the work proposed, which is judged largely on the previous college record.
Candidates whose engineering background is judged to be deficient may be required to take additional coursework that may not be applied toward the degree. The adviser helps plan a program to remedy any such deficiencies, after students arrive at UCLA.
Entering students normally are expected to have completed the B.S. degree requirements with at least a 3.0 grade-point average in all coursework taken in the junior and senior years.
Students entering the Engineer/Ph.D. program normally are expected to have completed the requirements for the master's degree with at least a 3.25 grade-point average and to have demonstrated creative ability. Normally the M.S. degree is required for admission to the Ph.D. program. Exceptional students, however, can be admitted to the Ph.D. program without having an M.S. degree.
For information on the proficiency in English requirements for international graduate students, see Graduate Admission in the Graduate Study section of the UCLA General Catalog or refer to http://www.gdnets.uc.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; http://www.gre.org.
Departments and Programs of the School

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

Timothy J. Deming, Ph.D., Chair

Professors
Denise Aberle, M.D.
Timothy J. Deming, Ph.D.
Warren S. Grundfest, M.D., FACS
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor of Aeronautics)
Gerard C.L. Wong, Ph.D.

Associate Professors
James Dunn, M.D., Ph.D.
Daniel T. Kamei, Ph.D.
Jacob J. Schmidt, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.

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

Adjunct Assistant Professors
Kayvan Niazi, Ph.D.
Shahrooz Rabizadeh, Ph.D.
Bill J. Tawil, M.B.A., Ph.D.

Scope and Objectives

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

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

Department Mission

Bioengineering is a diverse multidisciplinary field that has established itself as an independent engineering discipline. The school is developing a small yet innovative Bioengineering Department that is dedicated to producing graduates who are well-grounded in fundamental sciences and the rigorous analytical engineering tools necessary for lifelong success in the many possible bioengineering careers.

Undergraduate Program Objectives

The goal of the bioengineering curriculum is to provide 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 three main objectives: (1) to provide students with rigorous training in engineering and fundamental sciences, (2) to provide knowledge and experience in state-of-the-art research in bioengineering, and (3) to provide problem-solving and team-building skills to succeed in a career in bioengineering.

Undergraduate Study

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

Bioengineering B.S.

Capstone Major

Preparation for the Major

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

The Major

Required: Bioengineering 100, M106, 110, 120, 165EW (or Engineering 183EW or 185EW), 176, 180, Chemistry and Biochemistry 153A, Electrical Engineering 100; three technical breadth courses (12 units) selected from an approved list avail-

Apatite-coated poly(D,L-lactic-co-glycolic) acid (PLGA) scaffolds for bone tissue engineering.
able in the Office of Academic and Student Affairs; three capstone design courses (Bioengineering 182A, 182B, 182C); and three major field elective courses (12 units) from Bioengineering M104, M105, M131, M180L, 181L, 181L, 199 (8 units maximum), Biomedical Engineering C101, C102, CM103, CM140, CM145, CM150, CM150L, C170, C171, CM180, C181, CM183, C185, CM186B, CM186C, C187.

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.

Biomedical and Regenerative Medicine: Bioengineering M104, M105, 199 (8 units maximum), Biomedical Engineering CM140, CM183, C185, C187, Chemistry and Biochemistry C140, C181, Materials Science and Engineering 104, 110, 111, 120, 130, 132, 140, 143A, 150, 151, 160, 161, Molecular, Cell, and Developmental Biology 168. The above materials science and engineering courses may be used to satisfy the technical breadth requirement.

Biomedical Devices: Bioengineering M131, 199 (8 units maximum), Biomedical Engineering CM172, Electrical Engineering 102, CM150 (or Mechanical and Aerospace Engineering CM180), CM150L (or Mechanical and Aerospace Engineering CM180L), Mechanical and Aerospace Engineering C187L. The electrical engineering or mechanical and aerospace engineering courses listed above may be used to satisfy the technical breadth requirement.

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

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

Graduate Study

Although the graduate program in bioengineering is currently being developed, individuals who would like to conduct research in the laboratories of the professors in the Bioengineering Department should apply to the graduate program in the Biomedical Engineering Interdepartmental Program (http://www.bme.ucla.edu).

Faculty Areas of Thesis Guidance

Professors

Denise Aberle, M.D. (Kansas, 1979)
Medical imaging informatics: imaging-based clinical trials, medical data visualization

Timothy J. Deming, Ph.D. (UC Berkeley, 1993)
Polymer synthesis, polymer processing, supermolecular materials, organometallic catalysis, biomaterials, polymers

Warren S. Fundenstuhl, M.D., FACSM (Columbia, 1980)
Excimer laser, minimally invasive surgery, biological spectroscopy

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular mechanics, nanofluids, and bio-nano research

Professor Emeritus

Hooshang Kangarloo, M.D. (Tehran, 1970)
Telemedicine, healthcare process modeling and evaluation, and imaging informatics

Associate Professors

James Dunn, M.D., Ph.D. (Harvard, MIT, 1992)
Tissue engineering, stem cell therapy, regenerative medicine

Daniel T. Kamei, Ph.D. (MIT, 2001)
Molecular cell bioengineering, rational design of molecular therapeutics, systems-level analysis of cellular processes, drug delivery, diagnostics

Jacob J. Schmidt, Ph.D. (Minnesota, 1999)
Bioengineering and biophysics at micro and nanoscales, membrane protein engineering, bioinorganic hybrid devices

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

Assistant Professors

Dino Di Carlo, Ph.D. (UC Berkeley, 2006)
Microfluidics, biomedical microdevices, cellular diagnostics, cell analysis and engineering

Andrea M. Kasko, Ph.D. (U. Akron, 2004)
Polymer synthesis, biomaterials, tissue engineering, cell-material interactions

Adjunct Professor

Stem cell identification, regenerative medicine, systems biology

Adjunct Assistant Professors

Kayvan Niazi, Ph.D. (UCLA, 2000)
Molecular and cellular bioengineering, immunotherapeutics

Shahroz Rabizadeh, Ph.D. (UCLA, 1999)
Molecular and cellular bioengineering, drug discovery in cancer and neurodegeneration

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

Lower Division Courses

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

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.

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

Upper Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites or corequisites: Electrical Engineering 1 or Physics 1C, and Mathematics 32B, 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)

M104, Physical Chemistry of Biomacromolecules. (4) (Same as Biomedical Engineering CM104.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A or 20B, 30A, Life Sciences 2, 3. 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 phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, stabilization of charged species, and separation and characterization of biomacromolecules. Letter grading. — Ms. Kasko (F)

M105, Biopolymer Chemistry and Bioconjugates. (4) (Same as Biomedical Engineering CM105.) Lecture, four hours; discussion, one hour; outside study, five hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Biopolymer chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medicinal diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers, Presentation and discussion of design and synthesis of synthetic biocjugates for some sample applications. Letter grading. — Mr. Deming (F)

M106. Topics in Biophysics, Channels, and Membranes. (4) (Same as Biomedical Engineering CM106.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 2, 3, 4, Mathematics 33B, Physics 1C, 4A, 4B. Coverage of depth in physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrostatics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conducton, dendritic integration. Letter grading. — Mr. Schmidt (F)
110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 100, Computer Science 31, 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 fluid, extracorporeal devices, tissue engineering systems, and bioartificial organs. Introduction to pharmacokinetic analysis. Letter grading.
Mr. Kamei (Sp)

Mr. Grundfest, Mr. Schmidt (Sp)

M131. Nanopore Sensing. (4) (Same as Biomedical Engineering CM131.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, Physics 1A, 1B, 1C. Analysis of sensors based on measurement of fluctuating ionic conductance through artificial or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Letter grading.
Mr. Grundfest, Mr. Schmidt (Sp)

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

M172. Design of Minimally Invasive Surgical Tools. (4) (Same as Biomedical Engineering CM172.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biopsy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Letter grading.
Mr. Grundfest (Sp)

Mr. Wu (Sp)

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

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

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

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

182A-182B-182C. Bioengineering Capstone Design I, II, III. (4-4-4) Lecture, two hours; laboratory, six hours; outside study, four hours. Lectures, design seminars, and discussions with faculty advisory panel. Working in teams, students compete to develop innovative bioengineering solutions to meet specific set of design criteria (design and make strongest self-assembled biorobot or most stable UCLA logo or most selective and efficient biomarker sensors, etc.). Letter grading. 182A. Requisites: course 120, Physics 4BL. Development, writing, and oral defense of student design proposals. 182B. Requisite: course 182A. Exploration of different experimental and computational methods. Ordering of specific materials and software that are relevant to student projects. 182C. Requisite: course 182B. Construction of student designs, project updates, presentation of final projects in written and oral format, and team competition.
Mr. Deming (Sp); 182A: F, 182B: W, 182C

M183. Targeted Drug Delivery and Controlled Drug Release. (4) (Same as Biomedical Engineering CM183.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapeutics require comprehensive understanding of modern biology, physiology, biomaterials, and engineering. Targeted delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacoepidemiology. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide spatial and temporal control of drug release. 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 release. Letter grading.
Ms. Kasko (F)

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

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

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

Interdepartmental Program

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http://www.bme.ucla.edu

James Dunn, M.D., Ph.D., Chair

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Alex Bui, Ph.D. (Radiological Sciences)
Mark S. Cohen, Ph.D. (Neurology, Psychiatry and Biobehavioral Sciences, Radiological Sciences)
Timothy J. Deming, Ph.D. (Bioengineering, Chemistry and Biochemistry)
Joseph J. DiStefano III, Ph.D. (Computer Science, Medicine)
James Dunn, M.D., Ph.D. (Bioengineering, Pediatric Surgery)
Chih-Ming Ho, Ph.D. (Bioengineering, Mechanical and Aerospace Engineering)
Jack W. Judy, Ph.D. (Electrical Engineering)
Karen M. Lyons, Ph.D. (Molecular, Cell, and Developmental Biology, Orthopaedic Surgery)
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Ren Sun, Ph.D. (Molecular and Medical Pharmacology)
Michael A. Teitell, M.D., Ph.D. (Pathology and Laboratory Medicine)
Benjamin M. Wu, D.D.S., Ph.D. (Bioengineering)

Professors
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Marvin Bergsneider, M.D. (Neurosurgery)
Francisco Bezanilla, Ph.D. (Physics)
Douglas L. Black, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)
Tony F.C. Chan, Ph.D. (Mathematics)
Samson Chow, Ph.D. (Molecular and Medical Pharmacology)
Mark S. Cohen, Ph.D. (Neurology, Psychiatry and Biobehavioral Sciences, Radiological Sciences)
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Linda L. Demer, M.D., Ph.D. (Cardiology, Physiology)
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Bruce S. Dunn, Ph.D. (Materials Science and Engineering)
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Alan Garfinkel, Ph.D. (Cardiology, Integrative Biology and Physiology)
Robin L. Garrell, Ph.D. (Chemistry and Biochemistry)
Warren S. Grundfest, M.D. FACS (Bioengineering, Electrical Engineering, Surgery)
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Chang-Jin Kim, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koeffer, M.D. (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
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Daniel S. Levi, M.D., Ph.D. (Pediatrics)
James C. Liao, Ph.D. (Chemical and Biomolecular Engineering)
Edward R.B. McCabe, M.D., Ph.D. (Human Genetics, Pediatrics)
Harry Mckellop, Ph.D., in Residence (Orthopaedic Surgery)
Ishvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Monboquette, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D. (Medicine)
Peter M. Narins, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
Michael Sofroniew, M.D., Ph.D. (Neurobiology)
Igor Spigelman, Ph.D. (Dentistry)
Ricky Taira, Ph.D, in Residence (Radiological Sciences)
Michael 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. Tiedball, Ph.D. (Integrative Biology and Physiology)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Arthur Toga, Ph.D. (Neurology)
Jeffrey Wang, M.D. (Orthopaedic Surgery)
David Wong, Ph.D. (Dentistry)
Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics, California NanoSystems Institute)

Professor Emeriti
Hooshang Kangarloo, M.D. (Pediatrics, Radiological Sciences)
Peter Tontonoz, M.D., Ph.D. (Pathology and Laboratory Medicine)
Benjamin M. Wu, D.D.S., Ph.D. (Bioengineering, Dentistry, Materials Science and Engineering)
Lily Wu, Ph.D. (Molecular and Medical Pharmacology, Urology)

Assistant Professors
James Bisley, Ph.D. (Neurobiology)
Louis Bouchard, Ph.D. (Chemistry and Biochemistry)
Dino DiCarlo, Ph.D. (Bioengineering)
Christopher Giza, Ph.D. (Surgery, Neurosurgery)
Thomas G. Graeber, Ph.D. (Molecular and Medical Pharmacology)
Xiao Hu, Ph.D., in Residence (Surgery, Neurosurgery)
Andrea M. Kasko, Ph.D. (Bioengineering)
Dejan Markovic, Ph.D. (Electrical Engineering)
Heather Maynard, Ph.D. (Chemistry and Biochemistry)
Aydogan Ozcan, Ph.D. (Electrical Engineering)
Matteo Pollegrini, Ph.D. (Molecular, Cell, and Developmental Biology)
Nader Pouratian, Ph.D. (Neurosurgery)
Tatiana Segura, Ph.D. (Chemical and Biomolecular Engineering)
Landan Shams, Ph.D. (Psychology)
Hsian-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
Zhouwen Tu, Ph.D. (Neurology)
R. Michael van Dam, Ph.D. (Molecular and Medical Pharmacology)
Xinshu Xiao, Ph.D. (Integrative Biology and Physiology)

Adjunct Professors
Boris Kogan, Ph.D. (Computer Science)
Howard Winet, Ph.D. (Bioengineering, Orthopaedic Surgery)

Adjunct Associate Professor
Daniel J. Valentinio, Ph.D. (Radiological Sciences)

Adjunct Assistant Professor
Bill J. Tawil, M.B.A., Ph.D. (Bioengineering)

Scope and Objectives
The Biomedical Engineering Interdepartmental Program trains specially qualified engineers and scientists to work on engineering applications in either medicine or biotechnology. Graduates apply engineering principles to current needs and contribute to future advances in the fields of medicine and biotechnology. Fostering careers in industry or academia, the program offers students the choice of an M.S. or Ph.D. degree in eight distinct fields of biomedical engineering.

In addition to selected advanced engineering courses, students are required to take specially designed biomedical engineering courses to ensure a minimal knowledge of the appropriate biological sciences. Students receive practical training via an M.S. or Ph.D. research thesis or dissertation in biomedical engineering. Faculty members have principal appointments in depart-
ments across campus and well-equipped laboratories for graduate student research projects.

Graduate Study
For information on graduate admission, see Graduate Programs, page 23.
The following introductory information is based on the 2010-11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www.gdnet.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 Biomedical Engineering Program offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Biomedical Engineering.

Biomedical Engineering M.S.
Students are expected to complete 42 units, which in most cases include either Biomedical Engineering C201, CM202, and CM203, or C204, C205, and C206, and two courses from their area of study. The M.S. degree is offered under both the thesis plan and comprehensive examination plan. Under the thesis plan, 8 units of thesis work may be applied toward the unit requirements for the degree. The comprehensive examination plan consists entirely of coursework (12 courses) and a comprehensive examination. Eight of the 12 courses must be graduate (200-level) courses, and students must maintain a grade-point average of 3.25 or better in all courses.

Fields of Study

Biomaterials, Tissue Engineering, and Biomechanics
Three subfieldsô biomaterials, biomaterials, and tissue engineeringô encompass this broad field. The properties of bone, muscles, and tissues, the replacement of natural materials with artificial compatible and functional materials such as polymer composites, ceramics, and metals, and the complex interactions between implants and the body are studied.

Course Requirements
Core Courses (Required). Biomedical Engineering C201, C204, C205, C206, CM250A, Electrical Engineering 100.
Electives. Students are expected to fulfill the remaining course requirements from courses in this group listed on the Biomedical Engineering website at http://www.bme.ucla.edu/academics/programs.

Biomedical Signal and Image Processing
The biomedical signal and image processing field encompasses techniques for the acquisition, processing, classification, and analysis of digital biomedical signals, images, and related information, classification and analysis of biomedical data, and decision support of clinical processes.
Sample applications include (1) digital imaging research utilizing modalities such as X-ray imaging, computed tomography (CT), and magnetic resonance (MR), positron emission tomography (PET) and SPECT, optical microscopy, and combinations such as PET/MR, (2) signal processing research on hearing to voice recognition to wireless sensors, and (3) bioinformatics research ranging from image segmentation for content-based retrieval from databases to correlating clinical findings with genomic markers. Graduates of the program integrate advanced digital processing and artificial intelligence technologies with healthcare activities and biomedical research. They are prepared for careers involving innovation in the fields of signal processing, medical imaging, and
medical-related informatics in either industry or academia.

**Course Requirements**

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

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

**Electives.** Biomedical Engineering M248, Biomedical Physics 200A, 200B, M219, 222, Computer Science 143, 161, Electrical Engineering 211B, 214B.

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

**Biosystem Science and Engineering**

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

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

**Course Requirements**

Biosystem science and engineering can serve as a minor field for other Ph.D. majors if students complete the following courses with a grade-point average of B+: Biomedical Engineering CM286B, M296A, and one additional graduate-level elective from the additional foundations or electives list.

**Core Courses (Required).** Biomedical Engineering C201, CM202, CM203, M286B, CM286C, and either M296A or Biomathematics 220.


**Medical Imaging Informatics**

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

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

**Course Requirements**


**Molecular and Cellular Bioengineering**

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

**Course Requirements**

**Core Courses (Required).** Biomedical Engineering C201, C204, C205, C206, and two courses from M184, M215, M225, CM245, C283, CM286B, CM286C, Bioengineering 100, Biomathematics 220, 2270, M271, Computer Science 170A, Mathematics 146, 151A, Physiological Science 134, Statistics 200B.

**Electives.** Students are expected to fulfill the remaining course requirements from courses in this group listed on the Biomedical Engineering website at http://www.bme.ucla.edu/academics/programs.

**Neuroengineering**

The neuroengineering field is a joint endeavor between the Neuroscience Interdepartmental Ph.D. Program in the Geffen School of Medicine and the Biomedical Engineering Interdepartmental Graduate Program in HSSeAS.

The objectives of the neuroengineering field are to enable (1) students with a background in engineering to develop and exe-
Biomedical engineering category: Biomedical Engineering C201, M261A, M261B, M261C.

Microelectromechanical systems (MEMS) category: Biomedical Engineering CM250A, Mechanical and Aerospace Engineering CM280L, 284.

Neuroscience category: Neuroscience M201, M273.


Students without previous exposure to MEMS should take Biomedical Engineering CM150L; those without previous exposure to neuroscience should take Physiological Science 111A; those without previous exposure to signal processing should take Electrical Engineering 102 and 113. Both courses are offered every term.

Seminars (First-Year). Two seminars in problem-based approaches to bioengineering are required. All first-year students take a new graduate seminar series in Winter and Spring Quarters which is co-taught each term by one instructor from HSSEAS and one from the Brain Research Institute. Each seminar introduces students to a single area of bioengineering and challenges them to develop critical skills in evaluating primary research papers and to design new approaches to current problems. Topics include pattern generation, sensory signal processing, initiation and control of movement, microsensors, neural networks, photonics, and robotics.

Research Seminars. In addition to the formal coursework listed above, all students attend a series of weekly research seminars that allow both students and faculty members to become more conversant with the broad range of subjects in bioengineering.

Seminars (Second-Year). All second-year students take a seminar course each term specifically designed for the bioengineering program. Each course is co-taught by one faculty member from the Brain Research Institute and one from HSSEAS and often include outside UCLA faculty speakers or members of the Industrial Advisory Board.

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.

Upper Division Courses

C101. Introduction to Biomedical Engineering. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Designed for physical sciences, life sciences, and engineering students. Introduction to wide scope of biomedical engineering via treatment of selected important individual topics by small teams of specialists. Concurrently scheduled with course C201. Letter grading. Mr. Kamei (F)

CM102. Basic Human Biology for Biomedical Engineers I. (4) (Same as Physiological Science CM102.) 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 basic biological activities and organization of human body (from 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 CM202. Letter grading.

Mr. Grundfest (F)


Mr. Grundfest (W)

CM104. Physical Chemistry of Biomacromolecules. (4) (Same as Bioengineering M104.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 30A, Life Sciences 2, 3. 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 phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, solvation of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C204. Letter grading. Ms. Kasko (F)

CM105. Biopolymer Chemistry and Biocongjugates. (4) (Same as Bioengineering M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Biocongjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of biocongjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical interaction, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presenation and discussion of design and synthesis of syn-
thetic bioconjugates for some sample applications. Concurrently scheduled with course C205. Letter grading.

CM106. Topics in Biophysics, Channels, and Membranes. (4) (Same as Bioengineering M106.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 30B, Computer Science CM130. Preparation: Bioengineering 100, 120, Life Sciences 2, 3, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course CM150L. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electromyophysics. Basic principles of ion selective electrodes in dielectric media, building on complexity to ultimately address action potentials and signal propagation in nerves. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nernst potential. Debye-Hückel, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C206. Letter grading.

Mr. Schmidt (W)

CM131. Nanopore Sensing. (4) (Same as Biotechnology M131.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Bioengineering 100, 120, Life Sciences 2, 3, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artificial or protein nanochannels. Introduction to electrical implications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse current, theory and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurement, ion noise, proteins, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C231. Letter grading.

Mr. Duff (F)

CM140. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aerospace Engineering 101, 102, 156A. Introduction to mechanical functions of human body; skeletal adaptation to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory studies and tests. Concurrently scheduled with course CM240. Letter grading.

Mr. Pham (W)

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

Mr. Liao (F)

CM150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (4) (Same as Electrical Engineering CM150L and Mechanical and Aerospace Engineering CM180L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course CM150L. Hands-on introduction to microfabrication technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microactuators, microvalves, microsensors, and microarrays. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250A. Letter grading.

Mr. Judy (F)

CM150T. Directed Research in Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (4) (Same as Electrical Engineering CM150L and Mechanical and Aerospace Engineering CM180L.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course CM150L. Hands-on introduction to microfabrication technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microactuators, microvalves, microsensors, and microarrays. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250A. Letter grading.

Mr. Judy (F)

CM163. Targeted Drug Delivery and Controlled Drug Release. (4) (Same as Bioengineering M163.) Lecture, three hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapeutics require comprehensive understanding of modern biology, physiology, biomaterials, and engineering. Targeted delivery of genes and drugs and their temporal control is of drug relevance in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug proteins and nucleic acids can be delivered through application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide sustained release and spatial control. Concurrently scheduled with course CM230. Letter grading.

Ms. Kasko (F)

M184. Introduction to Computational and Systems Biology. (4) (Same as Computational and Systems Biology M184.) Lecture, two hours; outside study, four hours. Requisites: Computer Science CM170A, CM210A. Course covers computational and systems modeling of dynamic biosystems and cellular interactions. Focus is on understanding fundamental mechanisms underlying various types of biological interactions. Concurrently scheduled with course CM270. Letter grading.

Mr. Duff (F)

CM265. Computational Systems Biology: Modelling and Simulation of Biological Systems. (5) (Same as Computational and Systems Biology M186 and Computer Science CM186B.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Corequisite: course C170L. Introduction to therapeutic and diagnostic use of energy delivery techniques. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide sustained release and spatial control. Concurrently scheduled with course CM250L. Letter grading.

Mr. Wu (Sp)


Mr. Grundfest (W)

CM172. Design of Minimally Invasive Surgical Tools. (4) (Same as Bioengineering M172.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Life Sciences 2, 3, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulations and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biopsy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Concurrently scheduled with course C272L. Letter grading.

Mr. DiStefano (F)

CM180. Introduction to Biomaterials. (4) (Same as Materials Science CM180.) Lecture, three hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20A, 20B, and CM202. Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course C205. Letter grading. Mr. Wu (Sp)

CM186. Computational Systems Biology: Mod- eling and Simulation of Biological Systems. (5) (Same as Computational and Systems Biology M186 and Computer Science CM186B.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electrical Engineering 172, Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes at multiple levels. Control system, multicompartamental, predator-prey, phar- macokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathe- matical models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM266B. Letter grading.

Mr. DiStefano (F)

CM186C. Thesis Research and Research Commu- nication in Computational and Systems Biology. (2 to 4) (Formerly numbered: CM186L.) (Same as Computational and Systems Biology M186 and Computer Science CM186CL.) Lecture, one hour; discussion, two hours; laboratory, one hour; outside study, eight hours. Requisite: course CM186B. Closely di- rected, interactive, and real research experience in active quantitative systems biology research labora- tory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capacities, and importance of preparation and writing reports explaining how to pro- ceed with research for results. Major empha-
sions on effective research reporting, both oral and written. Concurrently scheduled with course CM286C. Letter grading. Mr. DiStefano (Hy)

C187. Applied Tissue Engineering: Clinical and Industrial Perspectives. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L, and other organ 1 or 2. Overview of current technical aspects of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval protocols, and physical/chemical and biological testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, 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 C287. Letter grading. Mr. Wu (F)

188. Special Courses in Biomedical Engineering. (4) Lecture, four hours; outside study, eight hours. Special topics in biomedical engineering for undergraduates and professionals. Concurrently scheduled with courses 210D-210E, with permission of the instructor, to be offered on a trial basis, such as those taught by resident and visiting faculty members. May be repeated for credit. Letter grading.

Graduate Courses

C201. Introduction to Biomedical Engineering. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Designed for physical sciences, life sciences, and engineering students. Introduction to wide scope of biomedical engineering via treatment of selected important individual topics by small teams of specialists concurrently scheduled with course C101. Letter grading. Mr. Kamei (F)

CM202. Basic Human Biology for Biomedical Engineers I. (4) (Same as Physiological Science CM204.) 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 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 visualization of applications. Concurrently scheduled with course CM102. Letter grading. Mr. Grundfest (F)

CM203. Basic Human Biology for Biomedical Engineers II. (4) (Same as Physiological Science CM205.) Lecture, three hours; laboratory, two hours; outside study, six 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 modelingsimulations (immune regulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (diagnosis, artificial skin, pathogen detectors, ultrasound, birth-control drug delivery). Concurrently scheduled with course CM103. Letter grading. Mr. Grundfest (W)

C204. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L, 30A, Life Sciences 2, 3. 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 properties, phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, solvation of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course CM104. Letter grading. Mr. Nako (F)

C205. Biopolymer Chemistry and Bioconjugates. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course, one through course in chemistry of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, thiol-ene click, and other covalent linkers, depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic conjugates for some sample applications. Concurrently scheduled with course CM105. Letter grading. Mr. Deming (W)

C206. Topics in Biophysics, Channels, and Membranes. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Emphasis on topics such as protein conformation, solvation of biomacromolecules. Basic physical principles governing electrostatics in dielectric media, building on complexity to ultimately address action potentials and signal propagation in excitable cells (Pfaffman- and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course CM106. Letter grading. Mr. Schmidt (W)

M214A. Digital Speech Processing I. (Same as Electrical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Electrical Engineering 113. Theory and applications of digital processing of speech signals. Application of biomedical engineering techniques to speech synthesis, automatic recognition, and applications of digital processing of speech signals. Mathematical models of human speech production and perception mechanisms, speech analysis/synthesis techniques including linear prediction, filterbank models, and homomorphic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Ms. Alwan (W)

M215. Biochemical Reaction Engineering. (4) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, outside study, seven hours. Enforced requisites: Chemical Engineering 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. Letter grading. Mr. Liao (Sp)

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

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

220. Introduction to Medical Informatics. (2) Lecture, two hours; outside study, five hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to field. Definition of this emerging field of study; current research efforts, and future directions in research. Key issues in medical informatics to expose students to different application domains, such as information system architecture, data and process modeling, information extraction and representations, information retrieval and visualization, health services research, telemedicine. Emphasis on current research endeavors and applications. Mr. Sgarbossa (F)

C221. Human Anatomy and Physiology for Medical and Imaging Informatics I, II, III. (4-4-4) Lecture, four hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Preparation: introduction to anatomy and physiology, with particular emphasis on understanding and visualization of anatomy and physiology through medical images. Topics relevant to acquisition, representation, and anatomical knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastrointestinal/genitourinary, endocrine, and musculoskeletal systems. Letter grading. Mr. El-Saden (F)

223A-223B-223C. Programming Laboratories for Medical and Imaging Informatics I, II, III. (4-4-4) Lecture, four hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Preparation: introduction to software in other medical and imaging informatics core curriculum courses. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used in image processing and medical information system infrastructures. Letter grading. 223A, Requisite: Computer Science 31, 32, Programming in Computing 20A, 20B. Course 223A is requisite to 223B, which is requisite to 223C. Integrated with topics presented in course M227 to reinforce concepts presented within informatics course. Projects focus on understanding medical networking issues and implementation of basic protocols for healthcare environment, with emphasis on use of DICOM. Introduction to basic tools and methods used within informatics. 223B, Requisite: course 223A. Integrated with topics presented in courses 223A, M227, and M228 to reinforce concepts presented within informatics course. Projects focus on medical image manipulation and decision support systems. 223C, Requisite: course 223B. Exposure to programming concepts for medical imaging, with focus on basic abstraction techniques used to extract meaningful features from medical text and imaging data and visualize results. Integrated with topics presented in courses 224B and M226 to reinforce concepts presented within informatics course. Projects focus on medical information retrieval, knowledge representation, and visualization. Mr. Meng (F, W, Sp)

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

224B. Advances in Imaging Informatics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 224A. Overview of information retrieval techniques in medical imaging and informatics-based applications of imaging, with focus on advances in field. Introduction to core concepts in information retrieval (IR), reviewing seminal papers on evaluating

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IR systems and their use in medicine (e.g., teaching files, case-based retrieval, etc.). Medical content-based image retrieval (CBIR) as motivation for research, 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, and methods of relevance feedback exist. Recognition of images (e.g., perception, presentation). Discussion of more advanced methods now being pursued by researchers. Letter grading.

Mr. Morioka (Sp)

M225. Bioseparations and Bioprocess Engineering. (4) (Same as Chemical Engineering C225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for graduate students. Issues related to medical knowledge representation and its application in healthcare processes. Topics include data structures (representing biological data: conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for knowledge (data mining), statistical classifiers, and hierarchical classification), and basic information retrieval. Review of work in constructing ontologies, with focus on problems in implementation. Common medical ontologies, coding schemes, and standardized indexes terminologies (SNOMED, UMLS). Letter grading.

Mr. Monbouquette (W)

M226. Medical Knowledge Representation. (4) (Formerly numbered 226.) (Same as Information Studies M254.) Lecture, four hours; discussion, one hour; outside study, eight hours. Designed for graduate students. Issues related to medical knowledge representation and its application in healthcare processes. Topics include data structures (representing biological data: conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for knowledge (data mining), statistical classifiers, and hierarchical classification), and basic information retrieval. Review of work in constructing ontologies, with focus on problems in implementation. Common medical ontologies, coding schemes, and standardized indexes terminologies (SNOMED, UMLS). Letter grading.

Mr. Taira (Sp)

M227. Medical Information Infrastructures and Internet Technologies. (4) (Formerly numbered 227.) (Same as Information Studies M254.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to networking communication, and information infrastructures in medical environment. Exposure to basic concepts related to networking at several levels: low-level (TCP/IP, services), medium-level (network topologies), and high-level (distributed computing, Web-based services) implementations. Commonly used medical communication protocols (HL7, DICOM) and current medical information systems (EMCS). Advantages 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)

M228. Medical Decision Making. (4) (Formerly numbered 228.) (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 methodology, and algorithmic methods for decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing, and estimation. Focus on technical advances in medical decision support systems and expert systems, with review of classic and current research. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading.

Mr. Kohi (W)

C231. Nanopore Sensing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Bioengineering 100, 120, Life Sciences 2, 3, Physics 1A, 1B, 1C. Analysis of sensors based on measurement of ion current through artificial or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ionic conductance through pores and GtK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future direction of field. Concurrently scheduled with course CM131. Letter grading. Mr. Schmidt (F)

CM240. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM240.) Lecture, four hours; discussion, two hours; outside study, eight hours. Required: Mechanical and Aerospace Engineering 101, 102, 156A. Introduction to functional mechanical human body; skeletal adaptations to optimize load transfer, mobility, and function; biomechanical engineering and biomechanics applications. Heat and mass transfer, Fluid power. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

Mr. Gupta (W)

CM245. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering C245.) Lecture, four hours; discussion, one hour; outside study, eight hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, direct gene mutagenesis and protein engineering, polynucleotides and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading.

Mr. Liao (F)

M248. Introduction to Biological Imaging. (4) (Same as Biomedical Physics M248 and Pharmacology M248.) Lecture, three hours; laboratory, one hour; outside study, seven hours. Exploration of role of biological imaging in modern biology and medicine, including imaging physics, instrumentation, image processing, and image range of modalities. Practical experience provided through series of imaging laboratories. Letter grading.

CM250A. Introduction to Micromachining and Microelectromechanical Systems. (4) (Same as Electrical Engineering CM250A and Mechanical and Aerospace Engineering CM250A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to micromachining and microelectromechanical systems (MEMS) technology. Overview of key concepts and processes in fabrication of MEMS device. Concurrently scheduled with course CM250L. Letter grading.

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

Mr. Judy (W)

M252. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Formerly numbered 252B.) (Same as Electrical Engineering M252 and Mechanical and Aerospace Engineering M252.) Lecture, four hours; discussion, one hour; outside study, eight hours. Introduction to MEMS design. Design methods, device rules, and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced, with both foundry and non- foundry processes. Computer-aided design for MEMS. Design project required. Letter grading.

Mr. Wu (Sp)


ME248. Introduction to Biomedical Engineering. (4) (Same as Electrical Engineering M255 and Neuroscience M260.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 15 or 68. Introduction to principles and technologies that underlie the design of prosthetic devices, sensor systems, and control systems. Topics include bioelectricity and neurosurgical applications, process control, and stimulation. Topics include bioelectricity, electrophysiology (action potentials, local field potentials, EEG, ECOG), 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. Judy (Sp)


M263. Neuroanatomy: Structure and Function of Nervous System. (4) (Same as Neuroscience M203.) Lecture, three hours; discussion/laboratory, three hours. Anatomy of central and peripheral nervous systems at cellular histological and regional systems level, with emphasis on contemporary experimental approaches to morphological study of nervous system in discussions of circuitry and neurochemical anatomy of major brain regions. Consideration of representative vertebrate and invertebrate nervous systems. Letter grading.

C270. Energy-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications. Focus on unique problems and fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C170. Letter grading.

Mr. Grundlef (F)

C270L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) Laboratory, four hours; outside study, two hours. Corequisite: course C270. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include computer simulation of biological light propagation in tissue, measuring absorption spectra of tissue/tissue phantoms, making tissue phantoms, determination of optical properties of different tissues, mechanical and temperature distribution measurements. Concurrently scheduled with course C170L. Letter grading.
CM280. Introduction to Biomaterials. (4) Lecture, four hours; outside study, eight hours. Concepts of modern physical sciences, life sciences, and engineering majors. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy bio-logic. Concurrently scheduled with course C171. Letter grading. Mr. Grunfeld (W)

C272. Design of Minimally Invasive Surgical Tools. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biop- sy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel dev-ices. Concurrently scheduled with course CM172. Letter grading. Mr. Grunfeld (F)

CM280. Introduction to Biomaterials. (4) (Same as Materials Science CM280.) Lecture, four hours; discussion, three hours; dis- cussion study, one hour. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Concurrently scheduled with course CM150. Letter grading. Mr. Wu (W)

C281. Biomaterials-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requi- site: course CM280. In-depth exploration of host cellu- lar interactions in vascular regeneration, tissue interaction, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhe- sion, and role of mechanical factors. Concurrently scheduled with course C181. Letter grading. Mr. Wu (Sp)


C283. Targeted Drug Delivery and Controlled Drug Release. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. New therapeutics require understanding of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel dev-ices. Concurrently scheduled with course CM172. Letter grading. Mr. Wu (Sp)

M284. Functional Neuroimaging: Techniques and Applications. (3) (Same as Biomedical Physics M285, Neuroscience M285, Psychiatry M285, and Psychology M278.) Lecture, three hours. In-depth ex- amination of activation imaging, including fMRI and electrophysiological methods, data acquisition and analysis, experimental design, and results obtained thus far in human systems. Strong focus on understand- ing temporal and spatial resolution and spatial activation imag- ing paradigms, and how to interpret results. Labora- tory visits and design and implementation of function- al MRI experiment. S/U or letter grading.

C285. Introduction to Tissue Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineer- ing applies principles of biology and physical scienc- es to tissues, organs, and organisms. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently sched- uled with course CM286B. Letter grading. Mr. DiStefano (Sp)

CM286C. Thesis Research and Research Communication in Computational and Systems Biology. (2 to 4) (Formerly numbered CM286L.) (Same as Computer Science CM282B.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: course CM168B. Letter grading. Mr. DiStefano (F)

CM286C. Thesis Research and Research Communication in Computational and Systems Biology. (2 to 4) (Formerly numbered CM286L.) (Same as Computer Science CM282B.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: course CM168B. Letter grading. Mr. DiStefano (F)

C287. Applied Tissue Engineering: Clinical and Industrial Perspectives. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artifi- cial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, de- livery methods, FDA approval processes, and physi- cal/chemical and biological testing. Case studies in- clude skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kid- ney, and other organ systems. Industrial per- spectives of tissue engineering products. Manufactur- ing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices concurrently scheduled with course C187. Letter grading. Mr. Wu (F)

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

C295A. Biomaterial Research.

C295B. Biomaterials and Tissue Engineering Research. (Same as Computer Science M296C and Medicine M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM180 or Biometrics 220. Estimation methodology and and model parameter estimation algorithms for fitting dy- namic systems models to data. Model dis- crimination methods. Theory and algorithms for de- signing optimal experiments for developing and quan- tifying models, with special focus on optimal sampling schedules design for kinetic studies. Analysis of PC software for model building and optimal experimental design via applications in physiology and pharmacol- ogy. Letter grading. Mr. DiStefano (W)

C296C. Advanced Topics and Research in Biomedical Systems Modeling and Simulation. (4) (Same as Computer Science M296C and Medicine M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM180. Advanced study and analysis of current research and literature in research specialty of faculty member teaching course. Student presentation of ongoing research specialty. May be repeated for credit. S/U grading. Mr. Kogan (F;Sp)

298. Special Studies in Biomedical Engineering. (4) Lecture, four hours; outside study, eight hours. Study of selected topics in biomedical engineering taught by resident and visiting faculty members. Let- ter grading.

299. Seminar: Biomedical Engineering Topics. (2) Seminar, two hours; outside study, four hours. De- signed for biomedical engineering students. Seminar by leading academic and industrial biomedical engineers from UCLA, other universities, and bio- medical engineering companies such as Baxter, Am- gen, Medtronics, and Guidant on development and application of recent technological advances in disci- pline. Exploration of cutting-edge developments and challenges in wound healing models, stem cell biolo- gy, artificial organs, advanced imaging, nano- and micro-hybrid devices, scaffold engineer- ing, and bioinformatics. S/U grading.

Mr. Wu (F;Sp)

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

495. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, four hours. Limited to graduate biomedical engineering students. Required of all departmental teaching assistants. May be taken concurrently while holding TA appointment. Seminar on 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. Mr. Kamei (F)

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

597A. Preparation for M.S. Comprehensive Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate biomedical engineering students. Reading and preparation for M.S. comprehensive examination. S/U grading.

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

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

Chemical and Biomolecular Engineering

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Panagiotis D. Christofides, Ph.D.
Yoram Cohen, Ph.D.
James F. Davis, Ph.D., Associate Vice Chancellor
Robert F. Hicks, Ph.D.
Louis J. Ignarro, Ph.D. (Nobel laureate, Jerome J. Belzer Professor of Medical Research)
James C. Liao, Ph.D. (Chancellor's Professor)
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Professors Emeriti
Eldon L. Knuth, Ph.D.
Ken Nobe, Ph.D.
William D. Van Vorst, Ph.D.
Vincent L. Wilker, Ph.D.
A.R. Frank Wazzan, Ph.D., Dean Emeritus

Assistant Professors
Gerassimos Orkoulas, Ph.D.
Tatiana Segura, Ph.D.

Scope and Objectives

The Department of Chemical and Biomolecular Engineering conducts undergraduate and graduate programs of teaching and research that focus on the areas of cellular and biomolecular engineering, systems engineering, and advanced materials processing and span the general themes of energy/environment and nanotechnology. Aside from the fundamentals of chemical engineering (applied mathematics, thermodynamics, transport phenomena, kinetics, reactor engineering and separations), particular emphasis is given to metabolic engineering, protein engineering, systems biology, synthetic biology, bio-nano-technology, biomaterials, air pollution, water production and treatment, environmental multimedia modeling, pollution prevention, combinatorial catalysis, molecular simulation, process modeling/simulation/control/optimization/integration/synthesis, membrane science, semiconductor processing, chemical vapor deposition, plasma processing and simulation, electrochemistry and corrosion, polymer engineering, and hydrogen production.

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, is accredited by ABET and AIChE, 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 mission of the undergraduate program is to educate future leaders in chemical and biomolecular engineering who effectively combine their broad knowledge of mathematics, physics, chemistry, and biology 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 ABET-accredited 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 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.

**The Major**

*Required:* Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104AL, 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 two elective courses (8 units) from Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C125, C140. For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

**Biomedical Engineering Option**

**Preparation for the Major**

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

**The Major**

*Required:* Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 104AL, 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) Chemical Engineering 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 19 or http://www.registrar.ucla.edu/ge/.

**Environmental Engineering Option**

**Preparation for the Major**

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

**The Major**

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

A student works with a radical enhanced atomic layer deposition system.
The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104AL, 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, C140 (another chemical engineering elective may be substituted with approval of the faculty adviser).

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

Semiconductor Manufacturing Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104AL, 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 102, 103, 110L, M116L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

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 first term in residence.

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

Semiconductor Manufacturing

The requirements for the M.S. degree in the field of semiconductor manufacturing are 10 courses (44 units) and a minimum 3.0 grade-point average overall and in the graduate courses. Students are required to take Chemical Engineering 104C/104CL, C216, 270, 270R, Electrical Engineering 123A, Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical engineering or materials science and engineering electives must be selected, with a minimum of two at the 200 level. A total of at least five graduate (200-level) courses is required. Approved elective courses include Chemical Engineering C214, C218, C219, 223, C240, Electrical Engineering 124, 221A, 221B, 223, 224, Materials Science and Engineering 210, 223.

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

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

Comprehensive Examination Plan

The comprehensive examination plan is not available for fields other than semiconductor manufacturing.

For the semiconductor manufacturing field, when all coursework is completed, students should enroll in Chemical Engineering 597A to prepare for the comprehensive examination, which tests their knowledge of the engineering principles of semiconductor manufacturing. In case of failure, the examination may be repeated once with the consent of the graduate adviser.

Thesis Plan

Consult the graduate adviser. The thesis plan is not available for the semiconductor manufacturing field.
Chemical Engineering Ph.D.

Major Fields or Subdisciplines
Consult the department.

Course Requirements
All Ph.D. students must take six courses (24 units), including Chemical Engineering 200, 210, and 220. Two additional courses may 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.

Preliminary and Qualifying Examinations
All Ph.D. students must take a preliminary oral examination that tests their understanding of chemical engineering fundamentals in the areas of thermodynamics, transport phenomena, and chemical kinetics and reactor design. The examination normally is taken during the second term in residence, and a 3.33 grade-point average in graduate coursework is required to be eligible to take the examination. Students are asked to solve the examination problems in writing and then present them orally to a faculty committee. Students whose first degree is not in chemical engineering may petition to postpone the examination to the following year. Any student failing the Ph.D. preliminary examination may petition to reenter the Ph.D. program after successfully completing the requirements for the M.S., including an M.S. thesis. If the petition is granted, the student may be approved to take the preliminary examination concurrently with the master’s thesis defense.

After successfully completing the required courses and the preliminary oral examination, 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 of Chemical and Biomolecular Engineering, in accordance with University regulations.

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

The University Oral Qualifying Examination consists of an oral defense of the dissertation research proposal and is administered by the doctoral committee. The oral examination is held no less than two weeks after submitting the written 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 Chemical and Biomolecular Engineering Department at UCLA. The ‘outside’ member must be a UCLA faculty member outside the Chemical and Biomolecular Engineering Department.

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) DNA microarray printing and scanning facility, (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 multilayer laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and (10) phosphorimeter for biochemical assays involving radiolabeled compounds.

Microbial cells are genetically and metabolically engineered to produce novel compounds that are used as drugs, specialty chemicals, 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 using DNA microarrays and RT-PCR. Such investigations are coupled with genomic and proteomic efforts, and mathematical modeling, to achieve system-wide understanding of the cell.

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

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

**Electrochemical Engineering and Catalysis Laboratories**

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

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

**Electronic Materials Processing Laboratory**

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

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

**Materials and Plasma Chemistry Laboratory**

The Materials and Plasma Chemistry Laboratory is equipped with state-of-the-art instruments for studying the molecular processes that occur during chemical vapor deposition (CVD) and plasma processing. CVD is a key technology for synthesizing advanced electronic and optical devices, including solid-state lasers, infrared, visible, and ultraviolet detectors and emitters, solar cells, heterojunction bipolar transistors, and high-electron mobility transistors. The laboratory houses a commercial CVD reactor for the synthesis of III-V compound semiconductors. This tool is interfaced to an 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 biomedical, electronics, and aerospace fields. The laboratory is unique in that it characterizes the reactive species generated in atmospheric plasmas and their chemical interactions with surfaces.

**Polymer and Separations Research Laboratory**

The Polymer and Separations Research Laboratory is equipped for research on membranes, water desalination, adsorption, chemical sensors, polymerization kinetics, surfacing engineering with polymers and the behavior of polymeric fluids in confined geometries. Instrumentation includes a high resolution multiprobe Atomic Force Microscope (AFM) and a quartz crystal microbalance system for membrane and sensor development work. An atmospheric plasma surface structuring system is available for nano-structuring ceramic and polymeric surfaces for a variety of applications that include membrane performance enhancement and chemical sensor arrays. Analytical equipment for polymer characterization includes several high-pressure...
Process Systems Engineering Laboratory

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

Faculty Areas of Thesis Guidance

Professors

Jane P. Chang, Ph.D. (MIT, 1998)
Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry

Panagiotis D. Christofides, Ph.D. (Minnesota, 1996)
Process modeling, dynamics and control, computational and applied mathematics

Yoram Cohen, Ph.D. (Delaware, 1981)
Separation processes, graft polymerization, surface 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

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

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

James C. Liao, Ph.D. (Wisconsin, Madison, 1987)
Biochemical engineering, metabolic reaction engineering, reaction path analysis and control

Yunfeng Lu, Ph.D. (University of New Mexico, 1995)
Semiconductor manufacturing and nanotechnology

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

Harold G. Monbouquette, 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 antibiotics/antitumor products

Professors Emeriti

Eldon L. Knuth, Ph.D. (Caltech, 1953)
Molecular dynamics, thermodynamics, combustion, applications to air pollution control and combustion efficiency

Ken Nobe, Ph.D. (UCLA, 1996)
Electrochemistry, corrosion, electrochemical kinetics, electrochemical energy conversion, electrodeposition, nanoalloys, electrochemical treatment of toxic wastes, bioelectrochemistry

William D. Van Vorst, Ph.D. (UCLA, 1953)
Chemical engineering: thermodynamics, energy conversion, alternative energy systems, hydrogen- and alcohol-fueled engines

A.R. Frank Wazzan, Ph.D. (UC Berkeley, 1963)
Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer

Assistant Professors

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

Tatiana Segura, Ph.D. (Northwestern, 2004)
Dynamics, tissue engineering, substrate-mediated non-viral DNA delivery

Lower Division Courses

2. Technology and Environment. (4)

Lecture, four hours; outside study, eight hours. Natural and anthropogenic flows of materials at global and regional scales. Case studies of natural cycles include global warming (CO2 cycles), stratospheric ozone depletion (chlorine and ozone cycles), and global nitrogen cycles. Flow of materials in industrial economies compared and contrasted with natural flows; presentation of lifecycle methods for evaluating environmental impact of processes and products. P/NP or letter grading.

Mr. Manousiouthakis (not offered 2010-11)

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. Monbouquette (F)

19. Fiat Lux Freshman Seminars. (1)

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

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

Upper Division Courses

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

Mr. Cohen, Mr. Hicks (F)

101A. Transport Phenomena I. (4)


Mr. Cohen, Mr. Hicks (W)

101B. Transport Phenomena II: Heat Transfer. (4)

Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A. Introduction to analysis of heat transfer in chemical, biological, materials, and molecular processes. Fundamentals of thermal energy transport, molecular-level heat transfer in gases, liquids, and solids, forced and free convection, radiation, and engineering analysis of heat transfer in process systems. Letter grading.

Ms. Chang, Ms. Hicks (W)

101C. Mass Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101B. Introduction to analysis of mass transfer in systems of interest to chemical engineering practice. Fundamentals of mass species transport, Fick law of diffusion, diffusion in chemically reactive flows, interphase mass transfer, multicomponent systems. Letter grading.

Mr. Cohen, Mr. Hicks (Sp)

102A. Thermodynamics I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102A. 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.

Mr. Lu, Mr. Orkoulas (W)

102B. Thermodynamics II. (4) (Formerly numbered 102.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102A. Fundamentals of chemical and statistical thermodynamics in chemical and biological sciences. Phase

Mr. Lu, Mr. Orkoulas (Sp)

103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101B. Application of principles of heat, mass, and momentum transport to design and operation of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading. Ms. Chang, Mr. Senkan (Sp)

104AL. Chemical and Biomolecular Engineering Laboratory I. (4) Laboratory, six hours; discussion, one hour; outside study, five hours. Requisites: courses 100, 101B, 102B. Not open for credit to students with credit for former course 104A. Measurement of temperature, pressure, flow rate, viscosity, and fluid composition in chemical processes. Methods of data acquisition, equipment selection and fabrication, and laboratory safety. Completion of unstructured engineering design project. Development of written and oral communication skills. Letter grading. Mr. Monbouquette (W,Sp)

104B. Chemical and Biomolecular Engineering Laboratory II. (4) Laboratory, four hours; discussion, eight hours; outside study, four hours; other, four hours. Requisites: courses 101C, 103, 104AL. 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 procedures, scaleup and process design, and error analysis. Letter grading. Mr. Senkan (F)

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Requisite: course 101C. Corequisite: course 104CL. Basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metalization, and metallization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Ms. Chang, Mr. Hicks (Sp)

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, metalization, and metallization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Ms. Chang, Mr. Hicks (Sp)


104DL. Molecular Biotechnology Laboratory: From Gene to Product. (4) Laboratory, eight hours; outside study, seven hours. Requisites: courses 101C, 102C, 104CL. Corequisite: course 104D. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid, transformation of construct into E. coli, production of gene product in bioreactor, downstream processing of bioreactor broth to purify recombinant protein, and characterization of purified protein. Letter grading. Ms. Segura, Mr. Tang (F,W,Sp)

105. Chemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101C, 102B. Fundamentals of chemical kinetics and catalysis. Introduction to analysis and design of homogeneous and heterogeneous chemical reactors. Letter grading. Mr. Senkan (F)

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 start-up behavior of chemical engineering processes. Chemical process control elements. Design and applications of chemical process computer control. Letter grading. Mr. Christofides, Mr. Manousiouthis (W)

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103 or (C125, 104AL, 106 or (C115). Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering principles with business principles for purpose of designing chemical processes and evaluating alternatives. Letter grading. Mr. Christofides, Mr. Manousiouthis (Sp)

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

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Computer Science 31. Numerical methods for computation of solution of systems or linear and nonlinear algebraic equations, ordinary differential equations, and partial equations. Chemical engineering examples used throughout to illustrate application of these methods. Use of MATLAB as platform (programming environment) to write programs based on numerical methods presented throughout course. Letter grading. Mr. Liao, Ms. Segura (F)

110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102A, 102B. An 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. Mr. Nobe (Not offered 2010-11)

111. Cryogenics and Low-Temperature Processes. (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 properties. May be concurrently scheduled with course C211. Letter grading. Mr. Manousiouthis (F)

112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 161A, 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 116A. Letter grading. Mr. Lu (W)

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, analysis of exposure, impact of pollution sources and control technology, and relationship of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading. Mr. Nobe (Not offered 2010-11)

114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metallic 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, electrodeposition, electroless deposition, batteries and fuel cells, electrochemical sensors, and biocorrosion. May be concurrently scheduled with course C214. Letter grading. Mr. Nobe (Not offered 2010-11)

115. 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 analysis of biological reactors. May be concurrently scheduled with course CM215. Letter grading. Mr. Liao, Ms. Segura (F)

116. 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 fabrication of crystalline and surfaces, analysis of structure and composition of crystals and their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading. Ms. Chang, Mr. Hicks (Sp)

118. Multimedia Environmental Assessment. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101A, 102B. Environmental impact assessment of technological innovations. Methods of assessment include analysis of inventories, mass balance, exposure assessment, and health risk assessment. May be concurrently scheduled with course 112. Letter grading. Mr. Cohen (Not offered 2010-11)


121. 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. Relevance of relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes and membrane support (flux and selectivity). Examples provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and bioelectronics.
medical devices. Concurrently scheduled with course C221. Letter grading.

Mr. Cohen (Not offered 2010-11)


Mr. Cohen (Not offered 2010-11)

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

Mr. Monbouquette (Sp)

CM127. Synthetic Biology for Biofuels. (4) Same as Chemistry CM127.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 153A, Life Sciences 3. Engineering microorganisms for complex phenotype is common goal of metabolic engineering 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 molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of systems modeling for metabolic engineering and synthetic microorganisms for energy applications. Concurrently scheduled with course CM227. Letter grading. (Not offered 2010-11)

C133. Frontiers in Biotechnology. (2) Same as Microbiology CM133.) Lecture, two hours. Requisites: Chemistry 153A and 153B, or Life Sciences 3 and 4, with grades of B or better. Integration of science and business in biotechnology. Coevolution with pharmaceutical, agricultural, and other key industries. Applications of biotechnology to improvement, devices, and other industry sectors. Academic research leading to licensing and founding of companies that turn research breakthroughs into marketable products. Stage design of research, development, and implementation. Staged financing and growth: private offerings, public offerings, deals, collaborations, outsourcing. Intellectual property, regulation, pricing, profits, risks, public perception. Building value, exit strategies, mergers and acquisitions. Concurrently scheduled with course CM233. P/NP or letter grading. (W)

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) Lyapunov stability for autonomous nonlinear systems including converse theorems, (2) input to state stability for interconnected systems, (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. (W)

Mr. Christofides (Sp)

C140. Engineering of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Technology of particle/gas systems with applications to gas cleaning, commercial products, and catalysis. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C240. Letter grading. (Not offered 2010-11)

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

Mr. Liao, Mr. Tang (F)

188. Special Courses in Chemical Engineering. (4) Ms. Seer, four hours; outside study, eight hours. Special topics in chemical 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: Chemical Engineer ing. (2 to 8) Tutorial, to be arranged. Limited to juniors; sophomores supervised individually. Investigation of selected topic under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F,W,Sp)

Graduate Courses

200. Advanced Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102B. Phenomenological and statistical thermodynamics of chemical and physical systems with engineering applications. Presentation of role of atomic and molecular spectra and intermolecular forces in interpretation of thermodynamic properties of gases, liquids, solids, and plasmas. Letter grading.

Mr. Nobe (F)

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 200 or Chemistry C223A or Physics 215A. Modern simulation of classical molecular systems. Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading.


Mr. Senkan (F)

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryogenic engineering 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 their special applications. Concurrently scheduled with course C111. Letter grading.

Mr. Manousiouthakis (Sp)


Mr. Wu (F)

C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemical engineering and applications including electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal and semiconduc tor surface finishing, passivity, electropolishing, electroless deposition, batteries and fuel cells, electrolysis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading.

Mr. Nobe (Not offered 2010-11)

CM215. Biochemical Reaction Engineering. (4) (Same as Biomedical Engineering 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 chemical and economic analysis of biological reactors. May be concurrently scheduled with course C115. Letter grading.

Mr. Liao, Ms. Segura (F)

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

Mr. Hicks (Sp) Mr. Hicks (F)

217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, convection, and electrode kinetics, along with applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading.

Mr. Nobe (F)


Mr. Cohen (Not offered 2010-11)


Mr. Manousiouthakis (Sp)

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

Mr. Cohen (F)
C221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Corequisites: courses 101A, 101B, 103. Fundamentals of membrane science and technology, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes and models of membrane transport (flux and selectivity) provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C211. Letter grading. Mr. Cohen (Not offered 2010-11)

C222. Stochastic Optimization and Control. (4) Lecture, four hours; laboratory, eight hours. Prerequisite: course 222A. Introduction to linear and nonlinear systems theory and estimation theory. Prediction, Kalman filter, smoothing of discrete and continuous systems. Stochastic systems with multiplicative noise. Applications to control of chemical processes. Stochastic optimization, stochastic linear and dynamic programming. S/U or letter grading. Mr. Manousiouthakis (W)

C233. Frontiers in Biotechnology. (4) (Same as Microbiology CM233.) Lecture, three hours. Requisites: Chemistry 153A and 153B and Life Sciences 3 and 4, with grades of B or better. Integration of science and business in biotechnology. Coevolution with pharmaceutical, agricultural, and other key industries, therapeutics, bioprocess engineering and design, and other industry sectors. Academic research leading to licensing and founding of companies that turn research breakthroughs into marketable products. Stages of product discovery and development. Staged financing and growth: private offerings, public offerings, deals, collaborations, outsourcing. Intellectual property, regulation, pricing, profits, risks, public perception. Building value, exit strategies, mergers and acquisitions. Concurrently scheduled with course CM133. S/U or letter grading. (W)

C234. Plasma Chemistry and Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate chemical engineering and engineering physics students. Application of chemistry, physics, and engineering principles to design and operation of plasma and ion-beam reactors used in etching, deposition, oxidation, and etching of materials by atomic, molecular, and ionic phenomena involved in plasma and ion-beam processing of semiconductors, etc. Letter grading. Ms. Chang, Mr. Hicks (Sp)

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

C236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 210, C216. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic de- vices. Topics include reactor design, transport phe- nomena, gas and surface chemical kinetics, structure and composition of deposited films, and relationship between process conditions and film properties. Letter grading. Mr. Hicks (W)


CM245. Molecular Biotechnology for Engineers. (4) (Same as Biomedical Engineering CM245S.) Lect- ture, four hours; discussion, one hour; outside study, eight hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical in- dustry today. Topics include recombinant DNA tech- nology, molecular research tools, manipulation of gene expression, directed mutation and protein engineering, DNA-based diagnostics and DNA mi- croarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading. Mr. Liao, Mr. Tang (F)


250. Computer-Aided Chemical Process Design. (4) Lecture, four hours; outside study, six hours. Requisite: course 108B. Application of optimization methods in chemical process design; computer aids in process engineering; process modeling; systemat- ic flowcharting, design and analysis of separation and design of operation of large-scale chemical process- ing systems. Letter grading. Mr. Manousiouthakis (F)


270. Principles of Reaction and Transport Phe- nomena. (4) Lecture, four hours; laboratory, eight hours. Fundamentals in transport phenomena, chem- ical reaction kinetics, and other high-temperature, mul- tiscale level. Topics include Boltzmann equation, micro- scopic chemical kinetics, transition state theory, and statistical analysis. Examination of engineering appli- cations related to state-of-art research areas in chemical engineering. Letter grading. Ms. Chang (W)

270R. Advanced Research in Semiconductor Manufacturing. (6) Laboratory, nine hours; outside study, nine hours. Limited to graduate chemical engi- neering students in M.S. semiconductor manufactur- ing option. Supervised research in processing semicon- ductor materials and devices. Letter grading.

M280A. Linear Dynamic Systems. (4) (Same as Electrical Engineering E280A and Mechanical and Aerospace Engineering ME270A.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engi- neering 141 or Mechanical and Aerospace Engineer- ing 171A. State-space description of linear time-in- variant (LTI) and time-varying (LTV) systems in con- tinuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular val- ues, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observabil- ity, realizability, and minimality. Stabilization design via state feedback and observer synthesis. Connections with transfer function techniques. Letter grading.
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 (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading.

M262A. Nonlinear Dynamic Systems. (4) (Same as Electrical and Mechanical and Aerospace Engineering M272A.) Lecture, four hours; outside study, eight hours. Requisite: course M260A or Electrical Engineering M240A or Mechanical and Aerospace Engineering M270A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading.

283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M260A, M262A. Designed for graduate students. Introduction to advanced dynamical systems 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 method, 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. Christofides


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. Pre-sentations 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. (FW,Sp)

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

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. Required of all new teaching assistants. Special seminar on communicating chemical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of grading, advising, and rapport with students. S/U grading.

495B. Teaching with Technology for Teaching Assistants. (2) Seminar, two hours; outside study, four hours. 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.

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. 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. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 12) Tutorial, 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 for 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.
engineering, hydrology and water resources engineering, and environmental engineering.

The ABET-accredited civil engineering curriculum leads to a B.S. in Civil Engineering, a broad-based education in structural engineering, geotechnical engineering, hydrology and water resources engineering, and environmental engineering. 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 structures (including structural/earthquake engineering and structural mechanics), geotechnical engineering, hydrology and water resources engineering, and environmental engineering. 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 objectives of the ABET-accredited 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, 1S; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1), 4AL.

**The Major**

Required: Mechanical and Aerospace 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 135B, one lecture course from Mechanical and Aerospace Engineering 135C, 137, 141, or 142, and one capstone design course from 135L, 142L, 144, or 147; recommended courses: 121, 125, 130, 137, 141, 142, 143, 144, 147; laboratory courses: 130L, 135L, 137L, 142L.

Additional Elective Options: Civil and Environmental Engineering 105, 106A, 180, 181, Earth and Space Sciences 100, Mechanical and Aerospace Engineering 166C, M168

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

**Environmental Engineering Minor**

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

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

**Required Lower Division Course (5 units):** Mathematics 3C or 32A.
Required Upper Division Courses (24 units minimum): Civil and Environmental Engineering 153 and five courses from 151, 154, 155, 156A, M166, Chemical Engineering C118, Environmental Health Sciences C125, C164.

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

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

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

The following introductory information is based on the 2010-11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www.gdnet.ucla.edu/gasaa/library/pgmrrqintro.htm. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

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

Civil Engineering M.S.

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

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

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

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

Environmental Engineering
Required Preparatory Courses: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 150 or 151, 153; Mathematics 32A, 33A; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.

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


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, 228L, 245.

Hydrology and Water Resources Engineering

Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 150 or 151, 153; Mathematics 32A, 32B, 33A; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.

Required Graduate Courses. Civil and Environmental Engineering 250A, 250B, 250C, and a minimum of three courses from 251A through 252, 253, 260.

Elective Courses. Civil and Environmental Engineering 150, 164, 254A, 255A, 255B, 263A; a maximum of two of the following courses for students electing the thesis plan or a maximum of three of the following courses for students electing the comprehensive examination plan: Atmospheric and Oceanic Sciences M203A, 218, Computer Science 270A, 271A, 271B, Electrical Engineering 236A, 236B, 236C, M237, Mathematics 269A, 269B, 269C.

Civil Engineering Ph.D.

Major Fields or Subdisciplines

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 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, 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 Civil and Environmental Engineering Department at UCLA. The outside member must be a UCLA faculty member outside the Civil and Environmental Engineering Department.

Fields of Study

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 engi-
neering 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 programs deal with hydrologic processes, statistics related to climate and hydrology, multiobjective water resources planning and management, numerical modeling of solute transport in groundwater, remediation studies of contaminated soil and groundwater, and optimization of conjunctive use of surface water and groundwater.

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

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

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

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

**Facilities**

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

**Instructional Laboratories**

**Advanced Soil Mechanics Laboratory**

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

**Environmental Engineering Laboratories**

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

**Mechanical Vibrations Laboratory**

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

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

**Reinforced Concrete Laboratory**

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

**Soil Mechanics Laboratory**

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

**Structural Design and Testing Laboratory**

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

**Research Laboratories**

**Building Earthquake Instrumentation Network**

The Building Earthquake Instrumentation Network consists of more than 100 earthquake strong motion instruments in three campus buildings to measure the response of actual buildings during earthquakes. When combined with over 50 instruments placed in four 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.

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

**Large-Scale Structure Test Facility**

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

**Facility Areas of Thesis Guidance**

**Professors Emeriti**

- Stanley B. Dong, Ph.D. (UC Berkeley, 1962)
- Lewis P. Felton, Ph.D. (Carnegie Institute of Technology, 1964)
- Michael E. Fourney, Ph.D. (Caltech, 1963)
- Gary C. Hart, Ph.D. (Stanford, 1968)

**Professors**

- Jia-Shyan (J-S) Chen, Ph.D. (Northwestern, 1989)
- Jonal P. Stewart, Ph.D. (UC Berkeley, 1996)
- Keith D. Stolzenbach, Ph.D. (MIT, 1971)
- John W. Wallace, Ph.D. (UC Berkeley, 1988)
- William G-W. Yeh, Ph.D. (Stanford, 1967)

**Assistant Professors**

- Christopher Tu, Ph.D. (UC Davis, 1975)
- Ne-Zheng Sun, Ph.D. (Shandong, 1985)
- Jiun-Shyan (J-S) Chen, Ph.D. (Northwestern, 1989)
- Keith D. Stolzenbach, Ph.D. (MIT, 1971)
- John W. Wallace, Ph.D. (UC Berkeley, 1988)
- William G-W. Yeh, Ph.D. (Stanford, 1967)

**Associate Professors**

- Scott J. Brandenberg, Ph.D. (UC Davis, 2005)
- Jiun-Shyan (J-S) Chen, Ph.D. (Northwestern, 1989)
- Keith D. Stolzenbach, Ph.D. (UC Berkeley, 1996)

**Senior Lecturer**

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

**Adjunct Professor**

- Ne-Zheng Sun, Ph.D. (Shandong, 1985)

Poul V. Ladef, Ph.D. (UC Berkeley, 1972) Soil mechanics, stress-strain and strength characteristics of soils, deformation and stability analyses of foundation engineering problems

Chung Yen Liu, Ph.D. (Caltech, 1962) Fluid mechanics, environmental, numerical

Richard L. Perrine, Ph.D. (Stanford, 1953) Resource and environmental problems: chemical, petroleum, or hydrological, physics of flow through porous media, transport phenomena, kinetics

Mohe F. Rubinstein, Ph.D. (UCLA, 1961) Systems analysis and design, problem-solving and decision-making models

Lucien A. Schmitt, Jr., M.S. (MIT, 1960) Structural mechanics, optimization, automated design methods for structural systems and components, applications of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components

Lawrence G. Selna, Ph.D. (UC Berkeley, 1967) Reinforced concrete, earthquake engineering
management, numerical analysis and optimization

Adjunct Associate Professors
Issam Najm, Ph.D. (Illinois, Urbana-Champaign, 1990)
Daniel E. Pradel, Ph.D. (U. Tokyo, 1987)

Soil mechanics and foundation engineering

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


distributed forces, determine and indeterminate force systems, shear and moment diagrams, and axia-

Lower Division Courses

1. Introduction to Civil Engineering. (2) Lecture, two hours; outside study, four hours. Introduction to scope of civil engineering profession, including earth-

2. Introduction to Computing for Civil Engineers. (2) Lecture, two hours; laboratory, two hours; outside study, two hours. Introduction to computer program-

3. Flat Lux Freshman Seminars. (1 Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty

4. Professional Practice Issues in Structural En-

5. Variable Topics in Civil and Environmental En-

6. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower

7. Statics and Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requi-

8. Principles of Soil Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: 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 de-

9. Soil mechanics and foundation engineering

10. 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. Site in-

11. 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. Site in-

12. 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. Site in-

13. Advanced Geotechnical Design. (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 prob-


15. Technical Communication. (4) Lecture, four hours; outside study, eight hours. Requisite: course 106. Techniques for effec-


17. Introduction to Probability and Statistics for Engineers. (4) Lecture, four hours; outside study, eight 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 de-

18. Statics and Dynamics. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisites: courses 15, Mathematics 33B (may be taken concurrently). Introduction to numeri-

19. Introduction to Computer Programming with MATLAB. Selected topics in programming with emphasis on numerical techniques and methodology as applied to civil engineering pro-

20. Intermediate Computer Programming for Civil Engineers. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 100. Concepts of control, data structures, and file management in MATLAB. Topics include arrays, strings, structures, functions, and graphical user interfaces. Letter grading. Mr. Chen (F, W)

21. Introduction to Soil Mechanics. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 100. Analysis and design of earthquake-resistant structures. Application of probabilistic methods to earthquake damage quantifica-

22. Dynamics of Beams and Frames. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 100, 121. Basic theory of beams and frames. Concepts of stress and strain, phenomenological material behavior, ex-

23. Field methods in physical and mechanical prop-

24. Experimental Structural Mechanics. (4) Lecture, two hours; laboratory, six hours. Collection, processing, and analysis of geospatial data. Geodetic models for shape of Earth. Elements and usage of topographic data and maps. Basic and advanced global position-

25. Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, eight hours; outside study, three hours. Requisite: or corequisite: course 120. Labora-

26. Variable Topics in Environmental Engineering. (2 to 4) Seminar, two hours; outside study, four hours. Topics in current environmental engineering issues, taught by faculty. Content and orga-

27. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 108. Analysis of stress and strain, phenomenonological material behavior, ex-


29. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

30. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

31. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

32. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

33. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

34. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

35. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

36. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

37. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

38. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

39. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

40. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.

41. Soil Mechanics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, six hours. Requisite: course 135A. Overview of engineering seismology and earthquake damage evaluation. Seismic hazard zoning, soil amplification, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands.
135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135A. Analysis of frames and frame structures using matrix methods; matrix force methods; matrix displacement method; analysis concepts based on theorem of virtual work; moment distribution. Letter grading. Mr. Ju (W)

MR135C. Introduction to Finite Element Methods. (4) (Formerly numbered 135C.) (Same as Mechanical and Aerospace Engineering M168.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mechanical and Aerospace Engineering 156A or 166A. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing techniques; term projects with computers. Letter grading. Mr. Chen (Sp)

135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 15, 135A. Limited enrollment. Computer-aided optimum design, construction 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. Ju (F-Sp)

137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics course for civil engineering students. Elastic free, forced vibration, and earthquake response spectra analysis for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams and columns. Simple connection design. Introduction to computer modeling methods and design process. Letter grading. Mr. Wallace (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibration of instrumentation for dynamic measurements. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic similitude. Letter grading. Mr. Ju (Not offered 2010-11)

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 structures. Design considerations and processes for structural steel members. Design of beams and beam columns. Simple connection design. Introduction to computer modeling methods and design process. Letter grading. Mr. Wallace (Sp)


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 (Sp)

143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Requisite: course 135A. Analysis of prestress and prestrain in prestressed concrete structures. Prestressing and post-tensioning techniques. Properties of concrete and prestressing steels. Design considerations: anchorage/bonding of cables/wire, flexure analysis by superposition and strength methods, drag and flyout, and indeterminate structures, limitation of prestressing. Letter grading. Ms. Zhang (Sp)


150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Mechanical and Aerospace Engineering 103. Recommended: courses 140 or 142. Examination of hydrologic cycle and relevant atmospheric processes, water and energy balance, radiation, precipitation formation, infiltration, evaporation, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading. Mr. Margulis (F)

151. Introduction to Water Resources Engineer- ing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: Mechanical and Aerospace Engineering 103. Principles of hydraulics, flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydroelectric power. Introduction to system simulation 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; outside study, four hours. Requisite: Mechanical and Aerospace Engineering 103. Water, air, and soil pollution: sources, transformations, effects, and processes for removal and disposal. Design of water and wastewater treatment, waste disposal, air pollution, global environmental problems. Field trip. Letter grading. Mr. Stolzenbach (F)

154. Chemical Fate and Transport in Aquatic En- vironments. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 153. Fundamental physical, chemical, and biological principles governing movement and fate of chemicals in surface waters and groundwater. Topics include physical transport in various aquatic environments, air-water exchange, acid-base equilibria, oxidation-reduction, colloids, and radionuclides. Excretion and bioaccumulation. Practical quantitative problems solved considering both reaction and transport of chemicals in environment. Letter grading. Ms. Jay (Sp)

155. Unit Operations and Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 153. Biological, chemical, and physical methods used to monitor water quality. Fundamental phenomena governing design of engineered systems for water and wastewater treatment systems. Field trip. Letter grading. Mr. Hoek (F)

158A. Environmental Chemistry Laboratory. (4) Lecture, four hours; outside study, four hours. Requisites: course 153 (may be taken concurrently), Chemistry 20A, 20B. Basic labo- ratory techniques in analytical chemistry related to water and wastewater analysis. Selected experiments include spectrophotometric analysis, redox systems, pH and electrical conductivity. Concepts to be applied to analysis of “real” water samples in course 158B. Letter grading. Mr. Stenstrom (Sp)

158B. Environmental Engineering Laboratory: Pro- cesses and Operations Laboratory. (4) Laboratory, six hours; discussion, two hours; outside study, four hours. Requisites: Chemistry 20A, 20B. Characterization and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chloride residual, that are used in unit operation experiments that include reactor dynamics, aeration, gas stripping, coagulation/floculation, and membrane separation. Letter grading. Mr. Stenstrom (W)

157A. Hydrologic Modeling. (4) Lecture, four hours; discussion, two hours; laboratory, four 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 separation of 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, two hours; discussion; two hours; laboratory, four hours; outside study, four hours. Requisite: course 155. Design of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and economics. Letter grading. Mr. Stenstrom (W)

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

157M. Hydrology of Mountain Watersheds. (4) Lecture, one hour; fieldwork, four hours; laboratory, three hours; outside study, one field trip. Requisite: course 150 or 157L. Advanced field- and laboratory-based course with focus 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 groundwaters through exploration of rating curves, stream classification, and flooding potential. Extended field trip required. Letter grading. Ms. Hogue (Sp)

163. Introduction to Atmospheric Chemistry and Air Pollution. (4) Lecture, four hours; outside study, eight hours. Requisites: course 153, Chemistry 20A, 20B, Mathematics 31A, 31B, Physics 1A, 1B. Description of processes affecting chemical composition of troposphere, air pollutant standards, urban and regional ozone, aerosol pollution, formation/deposition of acid precipitation, fate of anthropogenic/toxic/natural organic and inorganic compounds, and selected global control technologies. Letter grading. Mr. Stolzenbach (Sp)
Graduate Courses


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

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

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

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

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 125 (may be taken concurrently). 222. Analysis of earthquake-induced ground failure, including soil liquefaction, landslides, debris flows, soft soils, seismic compression, surface fault rupture, and seismic 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 (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, hazardous waste disposal, bioremediation, solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading. Mr. Stewart, Mr. Vuetic (Sp)

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of computer modeling of soils using finite element method, and to constitutive modeling based on elasticity and plasticity theories. Special emphasis on numerical applications and identification of modeling concerns such as instability, bifurcation, nonuniqueness, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vuetic (Sp)

228L. Advanced Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 120, 221, 222L. soils and laboratory studies covering more advanced aspects of laboratory determination 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. Vuetic (W)

M230A. Linear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A. Kinematics of material points, differentiation of material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of state, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (W)

M230B. Nonlinear Elasticity. (4) (Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course 156B. Kinematics of material points, differentiation of material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of state, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (W)

M230C. Plasticity. (Formerly numbered M239.) (Same as Mechanical and Aerospace Engineering M256C.) Lecture, four hours; outside study, eight hours. Requisites: Mechanical and Aerospace Engineering M256A, M256B. Classical rate-independent plasticity theory, yield functions, flow rules and thermodynamics. Classical rate-dependent viscoplasticity, strain-hardening, and Duvant's viscoplasticity. Thermoplasticity and creep. Return mapping algorithms for plasticity and viscoplasticity. Finite element implementations. Letter grading. Mr. Ju, Mr. Mal (Sp)

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


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

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

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, 235A. Direct energy formulations for deformable systems; solution methods for
linear equations; analysis of structural systems with one-dimensional elements; introduction to variational calculus; discrete element methods, 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 234A or nonlinear course 130 or 135B. Elastic buckling of bars. Different approaches to stability problems. Inelastic buckling of columns and beam columns. Columns and beam columns with linear, nonlinear creep. Combined torsional and flexural buckling of columns. Buckling of plates. Letter grading. Mr. Ju (Sp)


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


243A. Behavior and Design of Reinforced Concrete Structural Elements. (4) Lecture, four hours; outside study, eight hours. Requisite: course 142. Advanced topics on design of reinforced concrete structures, including stress-strain relationships for plain and confined concrete, moment-curvature analysis of sections, and design for shear. Design of slender and low-rise walls, as well as 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 and behavior of reinforced concrete buildings to earthquake ground motions. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, and ductility in design, use of prescriptive versus performance-based design methodologies, and application of elastic and inelastic analysis techniques for new and existing structures. Letter grading. Mr. Huang (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 systems, analysis of risk; calculation of capacity reduction factors. Letter grading. Mr. Ju (Not offered 2010-11)

245. Earthquake Ground Motion Characterization. (4) Lecture, four hours; outside study, eight hours. Requisite: course 137 or 246. Earthquake fundaments, 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. Stewart (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; earthquake motions related to earthquakes. Computational methods to evaluate structural response. Response analysis, including evaluation of contemporary design specifications. Limitations due to idealizations. Letter grading. Mr. Taciroglu (W)

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130 and 235A, or course 246. Concept of seismic isolation, linear theory of base isolation, visco-elastic and hysteretic behavior, elastomeric bearings under 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)


249. Soil and Groundwater Mechanics, and Geotechnical Engineering. (2) Lecture, two hours; outside study, six hours. Review of recent research and developments in structural engineering, soil mechanics, and geotechnical engineering. Structural analysis, finite elements, structural stability, dynamics of structures, structural design, earthquake engineering, ground motion, elasticity, plasticity, structural mechanics, mechanics of composites, constitutive modeling, geomaterials, and geotechnical engineering. May be repeated for credit. S/U grading. Mr. Ju, Mr. Stewart, Mr. Taciroglu, Mr. Wallace (F, W, 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 presentation 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. Ms. Hogue (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, global carbon exchange of mass, heat, and momentum between soil and vegetation surface and overlying atmosphere, flux and transport in turbulent boundary layer, basic remote sensing principles. Letter grading. Mr. Man (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 multifield planning and conjunctive use of surface water and groundwater. Emphasis on management of water quantity. Letter grading. Mr. Yeh (Sp)

251A. Rainfall-Runoff Modeling. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 254C, 254D. Introduction to hydrologic concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed model structure and calibration, parameter estimation, and application of models for flood forecasting and prediction of streamflows in water resource applications. Letter grading. Ms. Hogue (Sp)

251B. Contaminant Transport in Groundwater. (4) (Formerly numbered 251C.) 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 dispersion parameters by laboratory and field experiments, biological and reactive transport in multiphase flow, remediation design, software packages and applications. Letter grading. Mr. Yeh

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 evapotranspiration, soil moisture, and snow cover, vegetation, and precipitation. Letter grading. Mr. Margulis (Sp)

251D. Hydrologic Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic concepts of classical and Bayesian estimation theory for purposes of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models of hydrologic systems. Letter grading. Mr. Margulis (Sp)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 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)

M262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M262A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, thermochrometry, spectroscopy, and photochemistry; chemical composition and history of Earth's atmosphere; biogeochemical cycles of key atmospheric constituents; basic photometry of troposphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and climate. S/U or letter grading.

M262B. Atmospheric Diffusion and Air Pollution. (4) (Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complexes; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading.

M263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Transport processes in surface water, groundwater, and atmosphere. Emphasis on exchanges across phase boundaries: sediment/water interface; air/water gas exchange; particles, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading. Mr. Stolzenbach (W).

258A. Membrane Separations in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Applications of membrane separations to desalination, water reclamation, brine recovery, and ultrapure water purification. Consideration of reverse osmosis, ultrafiltration, electrodialysis, and ion exchange technologies from both practical and theoretical standpoints. Letter grading. Mr. Stenstrom (W).

258A. Membrane Separations in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Applications of membrane separations to desalination, water reclamation, brine recovery, and ultrapure water purification. Consideration of reverse osmosis, ultrafiltration, electrodialysis, and ion exchange technologies from both practical and theoretical standpoints. Letter grading. Mr. Stenstrom (W).

259A. Selected Topics in Environmental Engineering. (2 to 4) Lecture, two hours; outside study, four hours. Review of recent research and developments in environmental engineering. Water and wastewater treatment systems, nonpoint pollution, multimedia impacts. May be repeated for credit. S/U grading. Mr. Stolzenbach (F,W,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, economic planning, optimization of water resources development. May be taken for maximum of 4 units. Letter grading. Mr. Stenstrom (W,F,Sp).

260. Advanced Topics in Hydrology and Water Resources. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B, 250D. Current research topics in inverse problem of parameter estimation, experimental design, conjunctive 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 hydrodynamics, surface chemistry, adsorption and transport 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. Stenstrom (Sp).

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 pollutants, toxicity, and nutrients. Discussion of theoretical aspects, experimental observations, and recent literature. Application to important and emerging environmental problems. Letter grading. Mr. Stenstrom (Sp).

262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M262A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, thermochrometry, spectroscopy, and photochemistry; chemical composition and history of Earth's atmosphere; biogeochemical cycles of key atmospheric constituents; basic photometry of troposphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and climate. S/U or letter grading.

262B. Atmospheric Diffusion and Air Pollution. (4) (Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complexes; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading.

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Transport processes in surface water, groundwater, and atmosphere. Emphasis on exchanges across phase boundaries: sediment/water interface; air/water gas exchange; particles, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading. Mr. Stolzenbach (W).

263B. Advanced Topics in Transport at Environmental Interfaces. (4) Lecture, four hours; outside study, eight hours. Requisite: course 253A. In-depth treatment of selected topics involving transport phenomena at environmental interfaces between solid, fluid, and gas phases, such as aquatic sediments, porous aggregates, and vegetative canopies. Discussion of theoretical formulations and experimental observations. Application to important environmental engineering problems. Letter grading. Mr. Stolzenbach (Sp).

265A. Mass Transfer in Environmental Systems. (4) Lecture, four hours; computer applications, two hours; outside study, six hours. Requisites: courses 250B, 265A. Principles of mass transfer as they apply in soil and groundwater, independent estimation of transport model parameters; remediating hazardous waste sites. Letter grading. Mr. Stolzenbach (F).

265B. Contaminant Transport in Soils and Groundwater. (4) Lecture, four hours; computer applications, two hours; outside study, six hours. Requisites: courses 250B, 265A. Principles of mass transfer as they apply in soil and groundwater, independent estimation of transport model parameters; remediating hazardous waste sites. Letter grading. Mr. Stolzenbach (Sp).


269. 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. (F,W,Sp).

277. Seminar: Current 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. (F,W,Sp).

298. Seminar: 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. (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).

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

597A. Preparation for M.S. Comprehensive 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. (F,Sp).

597B. Preparation for Ph.D. Preliminary Examinations. (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. (F,Sp).

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. (F,Sp).
Computer Science

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Joseph J. DiStefano III, Ph.D.
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Milos D. Ercegovac, Ph.D.
Deborah L. Estrin, Ph.D. (Jonathan B. Postel Professor of Networking)
Eliezer M. Gafni, Ph.D.
Mario Gerla, Ph.D.
Richard E. Korf, Ph.D.
Christopher Lee, Ph.D.
Songwu Lu, Ph.D.
Rupak Majumdar, Ph.D.
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Rafael E. Osher, Ph.D.
Jens Palsberg, Ph.D.
D. Stott Parker, Jr., Ph.D.
Miodrag Potkonjak, Ph.D.
Amit R. Sarat, Ph.D.
Majid Sarrafzadeh, Ph.D.
Stefano Soatto, Ph.D.
Mani B. Srivastava, Ph.D.
Demetri Terzopoulos, Ph.D. (Chancellor's Professor)
Alan L. Yuille, Ph.D.
Carlo Zaniolo, Ph.D. (Norman E. Friedman Professor of Knowledge Sciences)
Lixia Zhang, Ph.D.
Song-Chun Zhu, Ph.D.

Professors Emeriti
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Rajive L. Bagrodia, Ph.D.
Bertram Russel, Ph.D.
Jack W. Carlyle, Ph.D.
Wesley W. Chu, Ph.D.
Gerald Estrin, Ph.D.
Thelema Estrin, Ph.D.
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Jacques J. Vidal, Ph.D.

Assistant Professors
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Adam W. Meyerson, Ph.D.
Zhuowen Tu, Ph.D.
Jennifer N. Vaughan, Ph.D.

Senior Lecturer
Leon Levine, M.S., Emeritus

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

Adjunct Professors
Alan Kay, Ph.D.
Boris Kogan, Ph.D.
Carey S. Nachenberg, Ph.D.
Ani Nahapetian, Ph.D.
Peter S. Pao, Ph.D.
Peter L. Reihem, Ph.D.
M. Yahya Sanadidi, Ph.D.

Scope and Objectives

Computer science is concerned with the design, modeling, analysis, and applications of computer-related systems. Its study at UCLA provides education at the undergraduate and graduate levels necessary to understand, design, implement, and use 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 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 computer engineering, in related engineering or application areas, and at the interface of computers and physical systems, (2) demonstrate strong communication skills and the ability to function effectively as part of a team, (3) demonstrate a sense of societal and ethical responsibility in their professional endeavors, and (4) engage in professional development or postgraduate education to pursue flexible career paths amidst future technological changes.

Computer Science Undergraduate Program Objectives

The computer science 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 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 ABET-accredited 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.

The computer science and engineering curriculum is accredited by the Computing Accreditation Commission and the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

Preparation for the Major

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

The Major

Required: Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), M152A (or Electrical Engineering M116L), 180, 181, Electrical Engineering 102, 110, 110L, 115A, 115C, Statistics 100A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Computer Science 152B); and three upper division computer science elective courses (12 units), one of which must be selected from Computer Science 143 or 161 or 174A. The remaining two elective courses must be selected from Computer Science 112, 113, M117 (or Electrical Engineering M117), CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130, 132, 133, 136, 143, 144, 151C, 161, 170A, M171L (or Electrical Engineering M171L), 174A, 174B, C174C, 183, M184 (or Biomedical Engineering M184 or Computational and Systems Biology M184), CM186B (or Biomedical Engineering CM186B or Computational and Systems Biology M186), CM186C (or Biomedical Engineering CM186C or Computational and Systems Biology M187). Electronic Engineering 103 may be substituted for one elective (credit is not given for both Computer Science 170A and Electrical Engineering 103 unless one of the courses is included in the technical breadth area); 4 units of either Computer Science 194 or 199 may be applied as an elective by petition.

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

Computer Science B.S.

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

The computer science curriculum is accredited by the Computing Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, (410) 347-7700.

Preparation for the Major

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

The Major

Required: Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), M152A (or Electrical Engineering M116L), 180, 181, Statistics 100A; three upper division science and technology courses (12 units) not used to satisfy other requirements, that may include three computer science courses or three courses selected from an approved list available in the Office of Academic and Student Affairs; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone software engineering or design course from Computer Science 130 or 152B; and six upper division computer science elective courses (24 units), two of which must be selected from Computer Science 143, 161, or 174A and one of which must be from 112 or 170A or Electrical Engineering 103 (credit is not given for both Computer Science 170A and Electrical Engineering 103 unless one of the courses is included in the technical breadth area); the remaining three elective courses must be selected from Computer Science 112, 113, M117 (or Electrical Engineering M116C), CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130, 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 Biomedical Engineering M184 or Computational and Systems Biology M184), CM186B (or Biomedical Engineering CM186B or Computational and Systems Biology M187).
medical Engineering CM186B or Computational and Systems Biology M186), CM186C (or Biomedical Engineering CM186 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 19 or http://www.registrar.ucla.edu/ge/.

**Graduate Study**

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

The following introductory information is based on the 2010-11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www.gdnet.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, 101, 102, 103, 110L, M116L, 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.

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

**Comprehensive Examination Plan**

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

**Thesis Plan**

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

The thesis is a report on the results of student investigation of a problem in the major field of study under the supervision of the thesis committee, which approves the subject and plan of the thesis and reads and approves the complete manuscript. While the problem may be one of only 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.

Students develop methods for outlier detection in Professor Eskin’s lab.
materials from both the M.B.A. Admissions Office, John E. Anderson Graduate School of Management, and the Department of Computer Science.

**Computer Science Ph.D.**

**Major Fields or Subdisciplines**

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

**Course Requirements**

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

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

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

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

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

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

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

**Written and Oral Qualifying Examinations**

The written qualifying examination consists of a high-quality paper, solely authored by the student. The paper can either be a research paper containing an original contribution or a focused critical survey paper. The paper should demonstrate that the student understands and can integrate and communicate ideas clearly and concisely. It should be approximately 10 pages single-spaced, and the style should be suitable for submission to a first-rate technical conference or journal. The paper must represent work that the student did as a graduate student at UCLA. Any contributions that are not the student’s own, including those of the student’s adviser, must be explicitly acknowledged in detail. Prior to submission, the paper must be reviewed by the student’s adviser on a cover page with the adviser's signature indicating review. After submission, the paper must be reviewed and approved by at least two other members of the faculty. There are two deadlines a year for submission of papers. After passing the preliminary examination and coursework for the major and minor fields, the student should form a doctoral committee and prepare to take the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, must hold appointments in the Computer Science Department at UCLA. The remaining member must be a UCLA faculty member outside the Computer Science 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 theo-
rem's, that require reasoning about relatively long sequences of primitive actions, deductions, or inferences

2. Knowledge representation and qualitative reasoning: Analysis of tasks such as commonsense reasoning and qualitative physics. Here the deductive chains are short, but the amount of knowledge that potentially may be brought to bear is very large

3. Expert systems: Study of large amounts of specialized or highly technical knowledge that is often probabilistic in nature. Typical domains include medical diagnosis and engineering design

4. Natural language processing. Symbolic, statistical, and artificial neural network approaches to text comprehension and generation

5. Computer vision. Processing of images, as from a TV camera, to infer spatial properties of the objects in the scene (three-dimensional shape), their dynamics (motion), their photometry (material and light), and their identity (recognition)

6. Robotics. Translation of a high-level command, such as picking up a particular object, into a sequence of low-level control signals that might move the joints of a robotic arm/hand combination to accomplish the task; often this involves using a computer vision system to locate objects and provide feedback

7. Machine learning. Study of the means by which a computer can automatically improve its performance on a task by acquiring knowledge about the domain

8. Parallel architecture. Design and programming of a machine with thousands or even millions of simple processing elements to produce intelligent behavior; the human brain is an example of such a machine

**Computational Systems Biology**

The computational systems biology (CSB) field can be selected as a major or minor field for the Ph.D. or as a specialization area for the M.S. degree in Computer Science.

Graduate studies and research in the CSB field are focused on computational modeling and analysis of biological systems and biological data.

Core coursework is concerned with the methods and tools development for computational, algorithmic, and dynamic systems network modeling of biological systems at molecular, cellular, organ, whole organism, or population levels and leveraging them in biosystem and bioinformatics applications. Methodological studies include bioinformatics and systems biology modeling, with focus on genomics, proteomics, metabolomics, and higher levels of biological/physiological organization, as well as multiscale approaches integrating the parts.

Typical research areas with a systems focus include molecular and cellular systems biology, organ systems physiology, medical, pharmacological, pharmacokinetic (PK), pharmacodynamic (PD), toxicokinetic (TK), physiologically based PBPK-PD, PBTK, and pharmacogenomic system studies; neurosystems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. Typical research areas with a bioinformatics focus include development of computational methods for analysis of high-throughput molecular data, including genomic sequences, gene expression data, protein-protein interaction, and genetic variation. These computational methods leverage techniques from both statistics and algorithms.

**Computer Networks**

The computer networks field involves the study of computer networks of different types, in different media (wired, wireless), and for different applications. Besides the study of network architectures and protocols, this field also emphasizes distributed algorithms, distributed systems, and the ability to evaluate system performance at various levels of granularity (but principally at the systems level). In order to understand and predict systems behavior, mathematical models are pursued that lead to the evaluation of system throughput, response time, utilization of devices, flow of jobs and messages, bottlenecks, speedup, power, etc. In addition, students are taught to design and implement computer networks using formal design methodologies subject to appropriate cost and objective functions. The tools required to carry out this design include probability theory, 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 intentionally to a certain body of knowledge emphasizing the interweaving themes of computability and algorithms, interpreted in the broadest sense. Under computability, one includes questions concerning which tasks can and cannot be performed by information systems of different types restricted in various ways, as well as the mathematical analysis of such systems, their computations, and the languages for communication with them. Under algorithms, one includes questions concerning (1) how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), (2) how efficiently a proposed system performs a task in terms of resources used, and (3) the limits on how efficiently a task can be performed. These questions are often addressed by first developing models of the relevant parts of an information processing system (e.g., the processors, their interconnections, their rules of operation, the means by which instructions are conveyed to the system, or the way the data is handled) or of the input/output behavior of the system as a whole. The properties of such models are studied both for their own interest and as tools for understanding the system and improving its performance or applications.

Computer System Architecture

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

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

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

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

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

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

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

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

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

Graphics and Vision


Information and Data Management

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

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

The need for rapid, accurate information is pervasive in all aspects of modern life. Modern systems are based on the coordination and integration of multiple levels of data representation, from characteristics of storage devices to conceptual and abstract levels. As human enterprises have become more complex, involving more complicated decisions and trade-offs among decisions, the need for sophisticated information and data management has become essential.
Software Systems
The programming languages and systems field is concerned with the study of theory and practice in the development of software systems. Well-engineered systems require appreciation of both principles and architectural trade-offs. Principles provide abstractions and rigor that lead to cleaner 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

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

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

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

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

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

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

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

Computer Graphics and Vision Laboratories
Center for Image and Vision Science (CIVS)
The Center for Image and Vision Science supports interdisciplinary research between the departments of Statistics and Computer Science in various aspects of visual modeling and inference. See http://civs.stat.ucla.edu/research.html.

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/wireless/.

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://iri.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/csd/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://dml.cs.ucla.edu/main.html.

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 investigating 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.mmmss.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.mmsl.cs.ucla.edu.

UCLA Web Information Systems Laboratory
The UCLA Web Information Systems Laboratory is used for investigating Web-based information systems. The laboratory seeks to develop the enabling technology for such systems by integrating the Web with database systems. Current projects focus on the preservation and warehousing of XML and database information to support temporal queries on historical archives, and data systems management systems to support advanced queries and data mining applications on the massive streams of information that are continuously flowing through the Web. See http://wis.cs.ucla.edu.

Software Systems Laboratories
Compilers Laboratory
The Compilers Laboratory is used for research into compilers, embedded systems, and programming languages.

Distributed Simulation Laboratory
The Distributed Simulation Laboratory is used for research on operating system support and applications and utilization of special architectures such as the Intel Hypercube.
Laboratory for Advanced System Research
The Laboratory for Advanced System Research is used for developing advanced operating systems, distributed systems, and middleware and conducting research in systems security.

Parallel Computing Laboratory
The Parallel Computing Laboratory is used for research in scalable simulation, providing an efficient lightweight simulation language, as well as tools for large-scale parallel simulation on modern supercomputers. See http://pcl.cs.ucla.edu.

Software Systems Laboratory
The Software Systems Laboratory is used for research into the design, implementation, and evaluation of operating systems, networked systems, programming languages, and software engineering tools. Some of these research laboratories also provide support for upper division and/or graduate courses.

Computing Resources
In summarizing the resources now available to conduct experimentally based research in the UCLA Computer Science Department, it is useful to identify the major components of the research environment: the departmental computing facility, other hardware and software systems, administrative structure, and technical support staff.

Hardware
Computing facilities range from large campus-operated supercomputers to a major local network of servers and workstations that are administered by the department computing facilities (DCF) or school network (SEASNet).

The departmental research network includes Sun 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 switched10/100/1000 ethernet to the desktop with a gigabit backplane 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
Alfonso F. Cardenas, Ph.D. (UCLA, 1969)
Database management, distributed heterogeneous and multimedia (text, image/picture, video, voice) systems, information systems planning and development methodologies, software engineering, medical informatics, legal and intellectual property issues
Tony F.C. Chan, Ph.D. (Stanford, 1978)
Image processing and computer vision, multi-level techniques for VLSI physical design, computational techniques for brain mapping
Jason (Jingsheng) Cong, Ph.D. (Illinois, 1990)
Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies
Adnan Y. Darwiche, Ph.D. (Stanford, 1993)
Knowledge representation and automated reasoning (symbolic and probabilistic), applications to diagnosis, prediction, planning, and verification
Joseph 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 (PKPD) modeling; knowledge-based (expert) systems for life science research
Michael G. Dyer, Ph.D. (Yale, 1982)
Artificial intelligence, natural language processing, connectionist, cognitive, and animat-based modeling
Milos D. Ercegovac, Ph.D. (Illinois, 1975)
Application-specific architectures, digital computer arithmetic, digital design, low-power systems, reconfigurable systems
Deborah L. Estrin, Ph.D. (MIT, 1985)
Sensor networks, embedded network sensing, environmental monitoring, computer networks
Eliezer M. Gafni, Ph.D. (MIT, 1982)
Computer communication, networks, mathematical programming algorithms
Mario Gerla, Ph.D. (UCLA, 1973)
Wireless ad-hoc networks; MAC, routing and transport protocols, vehicular communications, peer-to-peer mobile networks, sensor-area networks (Bluetooth and Zigbee), underwater sensor networks, Internet transport protocols (TCP, streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocol performance evaluation
Problem solving, heuristics search, planning in artificial intelligence
Lixia Zhang, Ph.D. (MIT, 1989)
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

Rupak Majumdar, Ph.D. (UC Berkeley, 2003)
Computer-aided verification of hardware and software systems; logic and automata theory; embedded, hybrid, and probabilistic systems

Stanley J. Osher, Ph.D. (NYU, 1986)
Scientific computing and applied mathematics

†Also Professor of Mathematics
Song-Chun Zhu, Ph.D. (Harvard, 1996)  
Computer vision, statistical modeling and computing, vision and visual arts, machine learning  

Professors Emeriti  
Digital computer architecture and design, fault-tolerant computing, digital arithmetic  
Rajee L. Bagrodia, Ph.D. (U. Texas, 1987)  
Wireless networks, nomadic computing, parallel programming, performance evaluation of computer and communication systems  
Bertram Russell, Ph.D. (UCLA, 1962)  
Computer systems architecture, interactive computer graphics  
Jack W. Carlyle, Ph.D. (UC Berkeley, 1961)  
Communication, computation theory and practice, algorithms and complexity, discrete system theory, developmental and probabilistic systems  
Wesley W. Chu, Ph.D. (Stanford, 1966)  
Distributed computing, distributed database, memory management, computer communications, performance measurement and evaluation for distributed systems and multiaccess packet-switched systems  
Gerald Estrin, Ph.D. (Wisconsin, 1951)  
Computer systems architecture, methodology and supporting tools for design of concurrent systems, automating design teamwork, reconfigurable architectures  
Thelma Estrin, Ph.D. (Wisconsin, 1951)  
Biomedical engineering, application of technology and computers to health care, computer methods in neuroscience, engineering education  
Sheila A. Greibach, Ph.D. (Harvard, 1963)  
Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability  
Leonard Kleinrock, Ph.D. (MIT, 1963)  
Computer networks, computer-communication systems, resource sharing and allocation, computer systems modeling analysis and design, queueing systems theory and applications, performance evaluation of congestion-prone systems, performance evaluation and design of distributed multiaccess packet-switching systems, wireless networks, mobile computing, nomadic computing, and distributed and parallel processing systems  
Allen Klinger, Ph.D. (UC Berkeley, 1966)  
Pattern recognition, picture processing, bio-inspired applications, mathematical modeling  
Lawrence P. McNamee, Ph.D. (Pittsburgh, 1964)  
Computer graphics, discrete simulation, digital filtering, computer-aided design, LSI fabrication techniques, printed circuit board design  
Michel A. Melkanoff, Ph.D. (UCLA, 1955)  
Programming languages, data structures, database design, relational models, simulation systems, robotics, computer-aided design and manufacturing, numerical-controlled machinery  
Multimedia systems, database systems, data mining  
Judea Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1965)  
Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference, causal and counterfactual analysis  
David A. Reynolds, Ph.D. (UCLA, 1973)  
Digital computer architecture and design, fault-tolerant computing, digital arithmetic  
Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems/ signal processing  

Associate Professors  
Junghoo (John) Cho, Ph.D. (Stanford, 2002)  
Databases, web technologies, information discovery and integration  
Ezeazer Eskin, Ph.D. (Columbia, 2002)  
Bioinformatics, genomics, genomics, machine learning  
Edward Kohler, Ph.D. (MIT, 2001)  
Operating systems, software systems, programming languages and systems, networking systems  
Programming language design, static type systems, formal methods, software model checking, compilers  
Gillian D. Reinman, Ph.D. (UC San Diego, 2001)  
Microprocessor architecture, exploitation of instruction/thread/memory/memory-level parallelism, power-efficient design, hardware/software code-design, multicore and multiprocessor design  
Theoretical computer science, cryptography, computer security, algorithmic and computational problems in networks and databases  
Yuvart Tamir, Ph.D. (Bellcore, 1985)  
Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliability, reconfigurable architectures, interconnection networks and switches, multi-core architectures, reconfigurable systems  

Assistant Professors  
Petros Faloutsos, Ph.D. (Toronto, 2002)  
Computer graphics, computer animation  
Adam W. Meyerson, Ph.D. (Stanford, 2002)  
Approximation algorithms, randomized algorithms, online algorithms, theoretical problems in networks and databases  
Zhuowen Tu, Ph.D. (Ohio State, 2002)  
Statistical modeling/computing, computational biology, machine learning, brain imaging  
Jennifer N. Vaughan, Ph.D. (U. Pennsylvania, 2009)  
Machine learning, computational/algorithmic economics, social network theory, algorithms  

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

Lecturers S.O.E.  
Paul R. Eggert, Ph.D. (UCLA, 1989)  
Programming languages, operating systems principles, compilers, Internet  
David A. Smallberg, M.S. (UCLA, 1998)  
Programming languages, software development  

Adjunct Professors  
Alan Kay, Ph.D. (Udah, 1969)  
Object-oriented programming, personal computing, graphical user interfaces  
Boris Kogan, Ph.D. (Moscow, Russia, 1962)  
Mathematical modeling and computer simulation (using parallel and distributed computers) of the dynamic processor in excitable biological systems, particularly mechanisms of heart arrhythmias, fibrillation and defibrillation  
Peter L. Reishur, Ph.D. (UCLA, 1987)  
Computer and network security, ubiquitous computing, file systems, distributed systems  
M. Yahya Sanadidi, Ph.D. (UCLA, 1982)  
Computer network security, performance evaluation of high speed packet switching systems  

Lower Division Courses  
1. Freshman Computer Science Seminar. (1 Seminar, one hour; discussion, one hour. Introduction to department resources and principal topics and key ideas in computer science and computer engineering. Assignments given to bolster independent study and writing skills. Letter grading. Mr. Cong (F)  
2. Great Ideas in Computer Science. (4 Lecture, four hours; outside study, eight hours. Broad coverage for liberal arts and social sciences students of computer science theory, applications, and implications, including artificial and neural machine intelligence, computability limits, virtual reality, cellular automata, artificial life, programming languages survey, and philosophical and societal implications. P/NP or letter grading. Mr. Dyer)  
19. Fiat Lux Freshman Seminars. (1 Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.  
31. Introduction to Computer Science I. (4 Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to computer science via theory, applications, and programming. Basic data types, operators and control structures. input/output, procedural and data abstraction. Introduction to object-oriented software development. Functions, recursion. Arrays, strings, pointers, data types, object-oriented programming. Examples and exercises from computer science theory and applications. Letter grading. Mr. Palsberg, Mr. Smallberg (F,W,Sp)  
33. Introduction to Computer Organization. (5 Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced requisite: course 32. Introductory course on computer architecture, assembly language, and operating systems fundamentals. Number systems, machine language, and assembly language, procedure calls, stacks, interrupts, and traps. Assemblers, linkers, and loaders. Operating systems concepts: processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading. Mr. Palsberg, Mr. Smallberg (F,Sp)  
35L. Software Construction Laboratory. (2 Laboratory; four hours; outside study, two hours. Requisite: course 31. Fundamentals of commonly used software tools and environments, particularly open-source tools to be used in upper division computer science courses. Letter grading. Mr. Eggert, Mr. Palsberg (F,Sp)  
M51A. Logic Design of Digital Systems. (4 Same as Electrical Engineering M51A) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms and control codes for digital information. Letter grading. Mr. Eregovac, Mr. Potkonjak (F,Sp)  
97. Variable Topics in Computer Science. (1 to 4) Lecture, one to four hours; discussion, zero to two hours. Designed for freshmen/transfer students. Variable topics in computer science covered in regular computer science courses. May be repeated once for credit with topic or instructor change. Letter grading. Mr. Smalberg
110. Operating Systems Principles. (5) Lecture, four hours; laboratory, two hours; outside study, nine hours. 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, Mr. Kohler (FW)

112. Computer System Modeling Fundamentals. (4) Lecture, four hours; discussion, two hours; outside study, two hours. Optional: courses 111, 112, 130, 131, 133. Study of fundamental concepts and protocols with emphasis on networking, peer-to-peer networks, such as distributed hash-tables, routing protocols, internet 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. Letter grading. Mr. Gerla, Ms. Zhang (FW,Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, three hours; discussion, one hour. Enforced requisites: course 180 or Program in Computing CM 100 or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A or 110A. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new bioinformatic methods. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM221. P/NP or letter grading. Mr. Eskin (F)

CM122. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Computer Science CM160B.) Lecture, four hours; laboratory, four hours. Enforced requisite: course CM121 or Chemistry CM160A with grade of C– or better. Recommended: Computer Science 30 or Program in Computing 60, Biostatistics 100A, 110A. Development and application of computational approaches to biological questions. Understanding of mechanisms for determining statistical significance of computational results. Development of foundation for innovative work in bioinformatics and systems biology. Concurrently scheduled with course CM222. Letter grading. Mr. Skrin (Not offered 2010-11)

CM124. Computational Genetics. (4) (Same as Human Genetics CM124.) Lecture, three hours; discussion, one hour; outside study, eight hours. Preparation: one semester of statistics or with an introduction to programming language. Designed for undergraduate and graduate engineering students, as well as students from biological sciences and medical school. Introduction to current quantitative understanding of human genetics and computational interdisciplinary research in genetics. Topics include introduction to genetics, human population history, linkage analysis, association analysis, genome design, isolated and admixed populations, population substructure, human structural variation, model organisms, and genotyping technologies. Computational techniques include theory 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. Requisites: courses 32, 35L. Recommended: Engineering 183EW or 185EW. Structured programming, program specification, program proving, modularity, abstract data types, composite design, software tools, software control systems, program testing, team programming. Letter grading. Mr. Eggert, Mr. Majumdar (W,Sp)

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Required: one course in programming design and use of programming languages, including abstraction, modularity, control mechanisms, types, declarations, syntax, and semantics. Study of several different language paradigms, including functional, object-oriented, and logic programming. Letter grading. Mr. Eggert, Mr. Millstein (F,Sp)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 35L, 131, 181. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; theory of parsing. Letter grading. Mr. Eggert, Mr. Paliszeg (W)

133. Parallel and Distributed Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 111 (may be taken concurrently), 131. Distributed memory and shared memory parallel architectures; asynchronous parallel languages: MPI, Maise; primitives for parallel communication; synchronization; design of parallel programs for scientific computation and distributed systems. Letter grading. Mr. Cong

136. Introduction to Computer Security. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 111, 118. Introduction to basic concepts of information security necessary for students to understand risks and mitigations associated with protection of systems and data. Topics include security models and architectures, security threats and risk analysis, access control and authentication/authorization, cryptography, network security, secure application design, and ethics and law. Letter grading. Mr. Eggert, Mr. Reifer (F)

143. Database Systems. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: course 32. Information systems and database systems in enterprises. File organization and secondary storage structures. Relational model and relational database systems. Network, hierarchical, and other models. Query languages. Database design principles, transactions, concurrency, and recovery. Integrity and authorization. Letter grading. Mr. Cardenas, Mr. Zanlioni (Sp)

144. Web Applications. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 180. Use of first-hand experience with basic tools. Topics include basic Web architecture and protocol, XML and XML query language, mapping between XML and relational models, information retrieval model and theory, security and user model, Web services and distributed transactions. Letter grading. Mr. Hostin, Mr. Reingad (Sp)

M151B. Computer Systems Architecture. (4) (Same as Electrical Engineering M116C.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 33, 51A or Electrical Engineering M16, Recommended: courses 111, and M152A or Electrical Engineering M116L. 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 subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Rengadh (F,Sp)


M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical Engineering M116L.) Laboratory, four hours; outside study, two hours. Requisite: course 51A or Electrical Engineering M16. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for synthesis and simulation of complex circuits using programmed array logic, design projects. Letter grading. Mr. Sarrafzadeh (F,Sp)

152B. Digital Design Project Laboratory. (4) (Formerly numbered M152B.) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisite: course 51B or Electrical Engineering M116C. Design and implementation of complex digital sub-systems using field-programmable gate arrays (FPGAs, e.g., Intel’s Field-programmable gate arrays, special-purpose processors, device controllers, and input/output interfaces). Students work in teams to develop and implement designs and to document their work and oral presentation of the results. Letter grading. Mr. Sarrafzadeh (F,Sp)
180. Introduction to Algorithms and Complexity. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 23 or 32, and Mathematics 61 or 180. Designed for junior/senior Computer Science majors. Introduction to design and analysis of algorithms. Design techniques: divide-and-conquer, greedy method, dynamic programming, selection, sorting, computational geometry, and probability. Analysis of data structures and representations; complexity measures: time, space, upper, lower bounds, asymptotic complexity, NP-complete problems. Mr. Gafni, Mr. Meyerson (F,W,Sp)

181. Introduction to Formal Languages and Automata Theory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 51 (or Program in Computing 10A), and Mathematics 61 or 180. Introduction to the theory of formal languages and automata. Context-free grammars, Pushdown automata, and languages. Finite-state languages and finite-state automata. Context-free languages and context-free grammars. Unrestricted grammars, recursively enumerable and recursive languages, and Turing machines. Closure properties, pumping lemmas, and decision algorithms. Introduction to computability. Letter grading. Ms. Greibach, Mr. Ostrovsky, Mr. Sahai (F,W,Sp)

183. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory, and basic mathematics (linear algebra, discrete math, number theory). Topics include: classical cryptography, symmetric-key cryptography, public-key cryptography, security (visual surveillance), and other models of data security. Topics include: symmet- ric-key encryption, key-agreement, homomorphic encryption, private information retrieval and voting protocols, message authentication, digital signatures, and interactive proofs. Mr. Mironov, Mr. Ostrovsky, Mr. SoRC (F,W)

192. Advanced Computer Science Seminar. (4) Seminar, four hours; outside study, eight hours. Designed for graduate students. Seminar on current research topics in computer science. May be repeated for credit. Letter grading. Mr. Estrin (F,S)

212A. Queueing Systems Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 118. Designed for graduate students. In-depth study of network protocols and computer systems software design in a working environment. Topics include: (1) queueing systems, (2) simulation techniques, (3) networking protocols, (4) performance evaluation. Mr. Lu (F,W)

212B. Queueing Networks Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: course 118. Designed for graduate students. In-depth study of queueing systems and network protocols. Topics include: (1) qualitative issues and theory of queueing (waiting-line) systems. Review of Markov chains and queueing theory. Method of stages. M/E/1, E/M/1. Bulk arrival and bulk service systems. Series-parallel stages. Fundamentals of open and closed queueing networks. Intermediate queueing theory: M/G/1; G/M/m. Collective marks. Advanced queueing theory: G/G/1; Lindley integral equation; queueing models; heavy traffic; bounds, approximations. Letter grading. Mr. Gerla

212B. Queueing Applications: Scheduling Algorithms and Queueing Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 212A. Prior and graduate applications to time-sharing scheduling algorithms: SF, Round Robin, Conserva-
tion Law, Bounds. Queueing networks: definitions; job flow balancing; product form solutions — local balance. (4) Lecture, four hours; outside study, eight hours. Requisite: course 111. Designed for graduate computer science and electrical engineering students. Methodologies and technologies for designing embedded systems. Topics include software and hardware platforms for embedded systems, techniques for modeling and specification of system behavior, software organization, real-time operating systems, real-time communication protocols, and packet scheduling, low-power battery and energy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Theoretical foundations as well as practical design methods. Letter grading. Ms. Potkonjak, Mr. Srivastava (F) M213B. Distributed Embedded Systems. (4) (Same as Electrical Engineering M202B.) Lecture, four hours; outside study, eight hours. Requisite: courses 111, and 118 or Electrical Engineering 132B. Designed for graduate computer science and electrical engineering students. Interdisciplinary course with topics of distributed embedded systems, including concepts needed to realize systems such as wireless sensor and actuator networks for monitoring and control of physical world. Topics include network self-configuration, wireless networks, and timing synchronization; energy-aware system design and operation; protocols for MAC, routing, transport, disruption tolerance; programming issues and models with language, OS, database, and middleware; in-network collaboration processing; fundamental characteristics such as coverage, connectivity, capacity, latency; techniques for exploitation and management of actuation and mobility; data and system integrity issues with calibration, faults, debugging, and security; and usage issues such as human interfaces and safety. Letter grading. Ms. Estrin, Mr. Srivastava (F) 214. Data Transmission in Computer Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112. Limited to graduate computer science students. Discrete data streams, formats, rates, retransmissions; digital data transmission via analog signaling in computer communication; media characteristics, systems methodologies, performance analysis; modern designs; physical interfaces; internet protocol design and specifications; ISO international standards; tests and measurements. Letter grading. Mr. Carlyle (W) 215. Computer Communications and Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 111. Review of computer traffic characterizations; multiplexing; network structure; packet switching and other switching techniques; ARPANET and other computer network examples: network delay, and analysis; network design and optimization; network protocols; routing and flow control; satellite and ground radio packet switching; local networks; commercial network services and architecture; Internet protocols include extended access control techniques; modems; SDLC, HDLC, X.25, etc.; protocol verification; network simulation and measurement; integrated networks; communication processes. Letter grading. Ms. Estrin (W) 216. Distributed Multicast Control in Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 212A, 215. Topics from field of distributed control and access in computer networks, including issues of network layering and design, satellite packet switching; ground radio packet switching; local network architecture and control. Letter grading. Mr. Kleinrock (W) 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 protocols, routing protocols, DNS, NTP, and security protocols such as DNSSEC, to understand principles behind design of these protocols, appreciate their design tradeoffs, and learn lessons from their operations. Letter grading. Ms. Zhang (F) 217B. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Requisite: course 217A. Designed for graduate students. Overview of Internet development history and fundamental protocols, software, and design research. Discussion of current Internet research topics, including latest research results in routing protocols, transport protocols, network measurements, network security protocols, and clean-slate approaches in network architecture design. Fundamental issues in network protocol design and implementations. Letter grading. Ms. Zhang (W) 218. Advanced Computer Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 112, 118. Review of seven-layer OSI/OSI model. High-speed networks: LANs, MANs, ATM. Flow and congestion control; bandwidth allocation, internetworking. Letter grading. Mr. Gerla (F) 219. Current Topics in Computer System Modeling. Analysis. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer system modeling analysis in which student 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. Ms. Estrin, Mr. Lu (Sp) CM221. Introduction to Computer Security. (4) (Same as Bioinformatics M260A, Chemistry CM260A, and Human Genetics M260A.) Lecture, three hours; discussion, one hour. Enforced requisites: course 180 or Program in Computing 60 with grade of C– or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A or 110A Introduction to bioinformatics and methodologies, with emphasis on concepts and recent new bioinformatics methods. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM121. S/U or letter grading. Mr. Eskin (F) CM222. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Chemistry CM260B.) Lecture, four hours; laboratory, four hours. Enforced requisite: course CM221 or Chemistry CM260A with grade of C– or better. Recommended: Computer Science 32 or Program in Computing 60, Statistics 100A, 110A. Development and application of computational approaches to biological questions. Understanding of mechanisms for determining statistical significance of computational results and development of foundation for innovative work in bioinformatics and systems biology. Concurrently scheduled with course CM221. Letter grading. Mr. Eskin (F) CM224. Computational Systems Genetics. (4) (Same as Human Genetics M229S.) Lecture, four hours; discussion, one hour; outside study, eight hours. Preparation: one statistics course and familiarity with any programming language. Designed for undergraduate and graduate engineering students, as well as students from biological sciences and medical school. Introduction to current quantitative understanding of human genetics and computational interdisciplinary research in genetics. Topics include introduction to genetics, human population history, linkage analysis, association analysis, and computational methodologies, such as coverage, connectivity, capacity, latency; techniques for exploitation and management of actuation and mobility; data and system integrity issues with calibration, faults, debugging, and security; and usage issues such as human interfaces and safety. Letter grading. (Mr. Eskin (Sp) M229S. Seminar: Current Topics in Bioinformatics. (4) (Same as Human Genetics M229S.) Seminar, four hours; outside study, eight hours. Designed for graduate engineering students, as well as students from biological sciences and medical school. Introduction to current topics in bioinformatics, genomics, and computational genetics and preparation for computational interdisciplinary research in genetics and genomics. Topics include genome analysis, regulatory genomics, association analysis, association study design, isolated and admixed populations, population 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 (W) 230A. Models of Information and Computation. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 131, 181. Introduction to models of computation, frameworks, and problem solving; UML and meta-modeling; basic information and computation models; axiomatic systems; domain theory; least fixed point theory; and structural induction. Logical models: syntax, axioms and rules, normal forms, derivation and proof, and models and semantics, propositional logic, first-order logic, logic programming. Functional models: algebraic specifications, equational logic, lambda calculus; functional programming. Program models: program derivation and verification using Hoare logic; object models, standard templates, design patterns, frameworks. Mr. Bagrodia, Mr. Parker, Mr. Zaniolo (W) 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 program verification and software reliability. Operational semantics, simply-typed lambda calculus, type soundness proofs, types for mutable references, types for exceptions. Parametric polymorphism, type systems, polymorphic type inference. Types for objects, subtyping, combining parametric polymorphism and subtyping. Types for modules, parameterized modules. Formal specification and implementation of type systems, as well as readings from recent research literature on modern applications of type systems. Letter grading. Mr. Mittelfeld (F) 232. Static Program Analysis. (4) Lecture, four hours; outside study, eight hours. Requisite: course 132. Introduction to static analysis of object-oriented programs and its usage for optimization and bug finding. Classical analysis techniques, flow-insensitive 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 optimization, deadlock detection, security vulnerability detection. Formal specification and implementation of variety of static analyses, as well as readings from recent research literature on modern applications of static analyses. Letter grading. Mr. Liu (F) 233A. Parallel Programming. (4) Lecture, four hours; outside study, eight hours. Requisite: 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 multeway rendezvous; synchronous and asynchronous languages; CSP, Ada, Linda, Maislie, 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, program correctness, live- ness, program and state assertion-based techniques, weakest precondition semantics, Hoare logic, temporal logic, UML, and model checking. Letter grading. 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 design and verification of computer 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 Operating Systems. (4) Lecture, four hours; preparation: C or C++ programming experience. Prerequisite: course 111. In-depth examination of operating systems issues through guided construction of research operating system for PC machines and consideration of recent literature. Memory management and protection, interrupts and traps, process synchronization, interprocess communication, preemptive multitasking, file systems. Virtualization, networking, profiling, research operating systems. Series of laboratory projects, including extra challenging work. Letter grade. Mr. Kohler (F)

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, common security tools, use of cryptographic 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. Palsberg, Mr. Reihman

239. Current Topics in Computer Science: Programming Languages and Systems. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer science programming languages and systems in which instructor has developed special proficiency as consequence of research interests. May be repeated for credit with topic change. Letter grade. Mr. Palsberg (P)

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 technologies, knowledge-based systems, and advanced programming environments. Rule-based knowledge representation, spatio-temporal reasoning, and logical-based declarative query/programming are central in this technology. Topics include object-relationship and data mining techniques. Letter grading. Mr. Zaniolo (W)

240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 143, 240A. Logical models for data and knowledge representations. Rule-based languages and nonmonotonic reasoning, Temporal queries, spatial queries, and uncertainty in deductive databases. Core course for core courses 143, 241A. Data types and user-defined column functions in ORDBs. Data mining algorithms. Semistructured information. Letter grading. Mr. Parker, 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 languages. Object data management standards. Extended relational-object systems. Database systems architecture and functional components. Systems comparison. Commercial products. Database design, organization, indexing, and performance. Future directions. Other topics at discretion of instructor. Letter grading. Mr. Cardenas (F)

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 databases: alphanumeric, long text, images/pictures, video, and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and architectures. Interconnection of multimedia, image, voice, and audio content. Querying, visual languages, and communication. Database design and organization, logical and physical. Indexing methods. Internet multimedia. Hypertext. Other topics at discretion of instructor. Letter grading. Mr. Cardenas (F)

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 systems, fault recovery techniques, network partitioning, examples, trade-offs, and design experiences. Letter grading. Mr. Chu

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 of database systems. Intelligent decision support systems, and intelligent planning and scheduling systems; computer architecture for processing large-scale knowledge-base/database systems. Letter grading. Mr. Chu

246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 112, 143, 180, 181. Designed for graduate students. Scale of Web data requires novel algorithms and principles for their management and retrieval. Study of Web characteristics and new management techniques needed to build computer systems suitable for the Web. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh techniques, Web.search ranking algorithms, and querying techniques on independent data sources. Letter grading. Mr. Cho (F)

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 topic change. Letter grade. Mr. Cardenas (W)

251A. Advanced Computer Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 111. Design and implementation of high-performance systems, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW processors, branch prediction, speculative execution, software support for instruction-level parallelism, simulation-based performance analysis and evaluation, state-of-art design examples, introduction to parallel architectures. Letter grading. Mr. Ercogevac, Mr. Tamir (F)

251B. Parallel Computer Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. SIMD and MIMD systems, symmetric multiprocessors, distributed-shared-memory systems, messages-passing systems, multiprocessors-cache coherent networks, host–network interfaces, switching element design, communication primitives, cache coherence, memory consistency models, synchronization primitives, state-of-the-art design examples. Letter grading. Mr. Ercogevac, Mr. Tamir (W)


253C. Testing and Testable Design of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 251A, 255A. Fundamental concepts of realistic problems in testing and testable designs of VLSI systems, including fault modeling, fault simulation, testing for single stuck faults and multiple stuck faults, functional testing, design for testability, compression techniques, and built-in self-test. Letter grading. Mr. Cong (W)

254A. Computer Memories and Memory Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 251A and/or 251B. Task partitioning and allocation, interprocess communication, task response time model, process scheduling, message passing protocols, replicated file systems, interface, cache memory, actor model, fine grain multicomputers, distributed memories, memory recovery strategy, performance monitoring and measurement, scalability and maintainability, prototypes and commercial distributed systems. Letter grading. Mr. Chu

255A. Advanced Scalable Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. State-of-art scalable multiprocessors. Interdependency among implementation technology, chip microarchitectures, and system architecture. High-performance building blocks, such as chip multiprocessors (CMP), coarse-grain distributed operating systems, network recovery strategy, performance monitoring and measurement, scalability and maintainability, prototypes and commercial distributed systems. Letter grading. Mr. Tamir

255B. Design of VLSI Circuits and Systems. (4) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisites: course M51A or Electrical Engineering M16, and Electrical Engineering 111A. Recommended: Electrical Engineering 111C. LSI/VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems. Other topics. Letter grading. Mr. Tamir

255C. LSI in Computer System Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M259A. LSI/VLSI design and application in computer systems. Other topics. Core courses 255B and/or 255C. Letter grading. Letter grading. Mr. Tamir

258E. Foundations of VLSI CAD Algorithms. (4) Lecture, four hours; outside study, eight hours. Preparation: one course in analysis and design of algorithms. Basic theory of combinatorial optimization for VLSI physical layout, including mathematical programming, network flows, matching, greedy and heuristic algorithms, and stochastic methods. Emphasis on practical application to computer-aided physical design of VLSI circuits at high-level phases of layout: partitioning, placement, routing, floorplanning, and global routing. Letter grading. Mr. Cong

258F. 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. Discussion of applications of number of important optimization techniques, such as network flows, Steiner trees, simulated annealing, and genetic algorithms. Letter grading. Mr. Cong

259G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M51A, 180. Detailed study of various problems in logic-level synthesis of VLSI digital sys
tems, including two-level Boolean network optimization; multilevel Boolean network optimization; technology modeling for cell design; and programmable gate-array (FPGA) designs; retiring 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. Requisites: courses M258A, M258F. Detailed study of various problems in analysis and design of high-speed VLSI interconnects at both integrated circuit (IC) and packing levels, including interconnect capacitance and resistance, lossless and lossy transmission lines, cross-talk and power distribution 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 topics to be repeated for credit with topic change. Letter grading. (F.W.Sp)

261A. Problem Solving and Search. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112 or equivalent probability. Study of fundamental properties of problem-solving search algorithms in artificial intelligence, including problem spaces, brute-force search, heuristic search, linear-space algorithms, real-time search, heuristic evaluation functions, two-player games, and constraint-satisfaction problems. Letter grading. Mr. Miller (Sp)

262A. Reasoning with Partial Beliefs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 262A. Machine representation of judgmental knowledge and uncertain relationships. Inference on inexact knowledge bases. Rule-based systems — principles, advantages, and limitations. Signal understanding. Automated planning systems. Knowledge acquisition and explanation producing techniques. Letter grading. Mr. Pearl

262C. Causal Inference. (4) (Same as Statistics M241.) Lecture, four hours; outside study, eight hours. Requisite: course 112 or equivalent probability theory course. Study of how computers interpret, summarize, and form theories of empirical observations. Mathematical analysis of trade-offs between computational complexity, storage requirements, and precision of computerized models. Letter grading. Mr. Pearl

262R. 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. Theory and implementation of systems that emulate or support human reasoning. Current literature 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. Introduction to natural language processing (NLP), with emphasis on semantics. Presentation of process models for various tasks, including question answering, paraphrasing, machine translation, word-sense disambiguation, narrative and editorial comprehension. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading. Mr. Dyer

263B. Connectionist Natural Language Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 263A. Examination of connectionist/ANN architectures designed for natural language processing. Issues include localist versus distributed representations, variable binding, instantiation and inference via spreading activation, acquisition of procedures, world knowledge instantiation, 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. Animats-Based Modeling. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Animats are mobile/sensing animats with emphasis on artificial life 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 (W)

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 unification, theorem proving, resolution, type theory, and logic algorithms for reasoning about power, satisfiability and entailment; syntactic 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


266A. Statistical Modeling and Learning in Vision and Science. (4) (Same as Statistics M232A.) Lecture, three hours. Preparation: basic statistics, linear algebra (matrix analysis), computer vision. Computational pattern and recognition. Study of four types of statistical learning visual patterns: descriptive, causal Markov, generative (hidden Markov), and discriminative. Comparison of principles and algorithms for these models; presentation of unifying picture. Introduction entropy and EM-type and stochastic algorithms for learning. SU or letter grading.

266B. 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 computing, sequential Monte Carlo methods, belief propagation, partial differential equations. SU or letter grading.

267A. Neural Models. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Review of major neurophysiological milestones in understating 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 motor function. Students required to prepare papers analyzing research in one area of interest. Letter grading. Mr. Vital

267B. Artificial Neural Systems and Connectionist Computing. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Analysis of 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. Assignments will be based on general multisenor pattern recognition including speed and vision, and adaptive robot control. Students required to prepare papers analyzing research in one area of interest. Letter grading. Mr. Vital


270S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for students undertaking thesis research. Discussion of advanced topics and current research in computational neuroscience. Neural networks and connectionism as paradigm for parallel and concurrent computation in application to problems of perception, vision, multimodal sensory integration, and robotics. May be repeated for credit. SU grading.

270X. Seminar: Current Topics in Artificial Intelligence. (2 to 4) Seminar, two hours; outside study, eight hours. Review of current literature and research practicum in area of artificial intelligence in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. Mr. Soatto, Ms. Vaughn (F.Sp)

270A. Computer Methodology: Advanced Numerical Techniques. (4) (Same as Statistics M151B) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 103 or Mathematics 151B or comparable experience with numerical computing. Designed for graduate computer science and engineering students. Principles of computer treatment of selected numerical problems in algebraic and differential systems, transforms and spectra, data acquisition and reduction; emphasis on concepts pertinent to models of complex and mixed reality computer and software systems. Letter grading.


271C. Seminar: Advanced Simulation Methods. (2) (Seminar, two hours; outside study, six hours. Required preparation: course 271A. Discussion of advanced topics in simulation of systems characterized by ordinary and partial differential equations. Topics include (among others) simulation languages, dataflow machines, array processors, and advanced mathematical simulation techniques. Topics vary each term. May be repeated for credit. SU grading.

272. Advanced Discrete Event Simulation and Modeling Techniques. (4) Lecture, four hours; outside study, eight hours. In-depth study of discrete event simulation and modeling techniques, including building valid and credible simulation models, output analysis of systems, comparisons of alternative system configurations. Various algorithms, simulation models of computer systems and manufacturing systems. Letter grading.
375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associ- ate, 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 ma- terials in classroom; preparation, organization of ma- terial, presentation, use of visual aids, grading, advis- ing, and rapport with students. S/U grading.

495B. Teaching with Technology. (2) Seminar, two hours; outside study, four hours. Limited to graduate Computer Science Department teaching assistants. Seminar for teaching assistants covering how tech- nology can be used to aid instruction in and out of classroom. S/U grading.

Mr. Korf

497D-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 in- vestigate as candidate for possible computerization, submitting team report of their findings and recom- mendations. In Progress (497D) and S/U or letter 497E) grading.

Mr. Cardenas

596. Directed Individual or Tutorial Studies. (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. Letter grading.

597A. Preparation for M.S. Comprehensive Exam- ination. (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 Examina- tions. (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 Examina- tion. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for oral qualifying examination, including preliminary re- search on dissertation. S/U grading.

598. Research 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 pro- spectus. S/U grading.

599. Research and Preparation of Ph.D. Dis- sertation. (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.
tronic, 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 ABET-accredited electrical engineering curriculum provides an excellent background for either graduate study or employment. Undergraduate education in the department provides students with (1) fundamental knowledge in mathematics, physical sciences, and electrical engineering, (2) the opportunity to specialize in specific areas of interest or career aspiration, (3) intensive training in problem solving, laboratory skills, and design skills, and (4) a well-rounded education that includes communication skills, the ability to function well on a team, an appreciation for ethical behavior, and the ability to engage in lifelong learning. This education is meant to prepare students to thrive and to lead. It also prepares them to achieve the following two program educational objectives: (1) that graduates of the program have successful technical or professional careers and (2) that graduates of the program continue to learn and to adapt in a world of constantly evolving technology.

Undergraduate Study
The Electrical Engineering major is a designated capstone major. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained in previous mathematics, science, and engineering coursework. Within a multidisciplinary team structure, students identify, formulate, and solve engineering problems and present their projects to the class.

Electrical Engineering B.S.
Capstone Major
The undergraduate curriculum allows Electrical Engineering majors to specialize in one of three emphasis areas or options. The three options are structured as an electrical engineering degree, and the only degree offered to undergraduate students by the department is the Bachelor of Science degree in Electrical Engineering. No distinction is made among the three options: (1) electrical engineering (EE) option is the regular option that provides students with preparation in electrical engineering with a range of required and elective courses across several disciplines; (2) computer engineering (CE) option provides students with preparation in embedded systems and software and hardware issues. Students replace some of the senior courses in the regular EE option with computer engineering-oriented courses or computer science courses; and (3) biomedical engineering (BE) option provides students with exposure to additional chemistry and life sciences courses and helps them meet most of the premedical preparation requirements so that they are prepared for careers in bioengineering, medicine, or electrical engineering.

Electrical Engineering Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical Engineering 1, 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL.
The Major

**Required:** Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115AL, 121B, 131A, 132A, 141, 161, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from one of the following pathways:

**Antennas and Microwaves:** Three major field elective courses from Electrical Engineering 162A, 163A, and 163B or 163C; one capstone design course from 164D or 184DA/184DB (count as one course); and one laboratory course from 164L (or by petition from 194 or 199)

**Integrated Circuits:** Three major field elective courses from Electrical Engineering 115B, 115C, and 132B or 163A; one capstone design course from 115D or 184DA/184DB (count as one course); and one laboratory course from 115BL (or by petition from 194 or 199)

**Microelectromechanical (MEMS) Systems:** Three major field elective courses from Electrical Engineering 115B or 123A or 124, 128 or 163A or 173, and CM150; one capstone design course from 129D; and one laboratory course from 122L or CM150L (or by petition from 194 or 199)

**Photonic and Plasma Electronics:** Three major field elective courses from Electrical Engineering 172, 173, and 174 or 175 or M185; one capstone design course from 173D; and one laboratory course from 172L (or by petition from 194 or 199)

**Signals and Systems:** Three major field elective courses from Electrical Engineering 114, 115B, 131B, 132B, 136, 142, 162A; one capstone design course from 113D, 173D, 180D, 181D, or 184DA/184DB (count as one course); and one laboratory course from 115BL or M116L or M171L (or by petition from 194 or 199)

**Solid State:** Three major field elective courses from Electrical Engineering 123A, 123B, and 124 or 128; one capstone design course from 129D; and one laboratory course from 122L (or by petition from 194 or 199)

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

**Biomedical Engineering Option**

**Preparation for the Major**

**Required:** Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL; Computer Science 31; Electrical Engineering 1, 2, 3, 10, M16 (or Computer Science M51A); Life Sciences 2, 3; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL.

**The Major**

**Required:** Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115AL, 131A, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from the biomedical engineering pathway as follows: three major field elective courses from Electrical Engineering 132A, 141, and 176 or Mechanical and Aerospace Engineering 105A; one capstone design course from Electrical Engineering 113D or 180D; and one laboratory course from Biomedical Engineering CM186C or Electrical Engineering M171L (or by petition from 194 or 199).

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

**Computer Engineering Option**

**Preparation for the Major**

**Required:** Chemistry and Biochemistry 20A; Computer Science 31, 32, 33, 35L; Electrical Engineering 1, 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL.

**The Major**

**Required:** Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115C, M116C (or Computer Science M151B), 131A, 132B or Computer Science 118, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from the computer engineering pathway as follows: three major field elective courses from Computer Science 111, M117 (or Electrical Engineering 132A), and 131 or 132 or 180; one capstone design course from Electrical Engineering 113D, 180D, 181D, or 184DA/184DB (count as one course); and one laboratory course from Electrical Engineering M116L (or by petition from 194 or 199).

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

**Graduate Study**

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

The following introductory information is based on the 2010-11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www.gdnet.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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

**Electrical Engineering M.S.**

**Areas of Study**

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. Students must select a number of formal graduate courses to serve as their major 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 reexamed 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

2. **Photonics and Plasma Electronics Track.** Courses deal with laser physics, optical amplification, electro-optics, acousto-optics, magneto-optics, nonlinear optics, photonic switching and modulation, ultrafast phenomena, optical fibers, integrated waveguides, photodetection, optoelectronic integrated circuits, optical micro electromechanical systems (MEMS), analog and digital signal transmission, photonics sensors, lasers in biomedicine, fundamental plasma waves and instability; interaction of microwaves and laser radiation with plasmas; plasma diagnostics; and controlled nuclear fusion. Courses include Electrical Engineering 270, 271, 272, 273, 274, 285A, 285B, M287

3. **Solid-State and Micro electromechanical Systems (MEMS) Devices Track.** Courses deal with solid-state physical electronics, semiconductor device physics and design, and micro electromechanical systems (MEMS) design and fabrication. Courses include Electrical Engineering 221A, 221B, 221C, 222, 223, 224, 225, CM250A, M250B, Mechanical and Aerospace Engineering 281, 284, C287L

### Signals and Systems Area Tracks

1. **Communications Systems Track.** Courses deal with communication and telecommunication principles and engineering applications; channel and source coding; spread spectrum communication; cryptography; estimation and detection; algorithms and processing in communication and radar; satellite communication systems; stochastic modeling in telecommunication engineering; mobile radio engineering; and telecommunication switching, queuing system, communication networks, local-area, metropolitan-area, and wide-area computer communication networks. Courses include Electrical Engineering 205A, 210A, 230A through 230D, 231A, 231E, 232A through 232E, 233, 238, 241A

2. **Control Systems and Optimization Track.** Courses deal with state-space theory of linear systems; optimal control of deterministic linear and nonlinear systems; stochastic control; Kalman filtering; stability theory of linear and nonlinear feedback control systems; computer-aided design of control systems; optimization theory, including linear and nonlinear programming; convex optimization and engineering applications; numerical methods; non-convex 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


### 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

For M.S. students following the non-thesis option, the M.S. comprehensive examination is satisfied by completion of Electrical Engineering 299 (project seminar) under the direction of a faculty member. Students are assigned some topic of independent study by the faculty member. The study culminates with a written report and an oral presentation. The M.S. project seminar program across the department is administered, for each student, by the faculty member directing the course, the director of the area to which the student belongs, and the departmental graduate adviser. In case of failure, students may be reexamined only once with consent of the departmental graduate adviser.

### 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, micro electromechanical 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 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, 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 Electrical Engineering Department at UCLA. The outside member must be a UCLA faculty member outside the Electrical Engineering Department. By petition, one of the four members may be a faculty member from another UC campus.

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 Electrical Engineering Department at UCLA. The outside member must be a UCLA faculty member outside the Electrical Engineering 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 Electrical Engineering Department at UCLA. The outside member must be a UCLA faculty member outside the Electrical Engineering 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 gigabit logic systems, 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
imaging systems for telemedicine needs.

Professor Ozcan and students work in the Bio- and Nano-Photonics Laboratory on developing next-generation 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/ class 1000 clean room with a full complement of utilities, including high purity deionized water, high purity nitrogen, and exhaust scrubbers. The NRF supports research on nanometer-scale fabrication and on the study of fundamental quantum size effects, as well as exploration of innovative nanometer-scale device concepts. The laboratory also supports many other schoolwide programs in device fabrication, such as MEMS and optoelectronics. For more information, see http://www.nanolab.ucla.edu.

Photonics and Optoelectronics Laboratories
In the Laser Laboratory students study the properties of lasers and gain an understanding of the application of this modern technology to optics, communication, and holography.

The Photonics and Optoelectronics Laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrafast lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al2O3 lasers, ultraviolet and visible wavelength argon lasers, wavelength-tunable dye lasers, as well as gallium arsenide, helium-neon, excimer, and high-powered continuous and pulsed carbon dioxide laser systems. Also available are equipment and facilities for research on semiconductor lasers, fiber optics, nonlinear optics, and ultrashort laser pulses. Facilities for mirror polishing and coating and high-vacuum gas handling systems are also available. These laboratories are open to undergraduate and graduate students who have faculty sponsorship for their thesis projects or special studies.

Plasma Electronics Facilities
Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art table top terawatt (T3) 400fs laser system that can be operated in either a single or dual frequency mode for laser-plasma interaction studies. Diagnostic equipment includes a ruby laser scattering system, a streak camera, and optical spectrographs and multichannel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing. The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focusable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS; other equipment includes a theta-pinch plasma generator, an electron linac injector, and electron detectors and analyzers.

A second group of laboratories is dedicated to basic research in plasma sources for basic experiments, plasma processing, and plasma heating.

Solid-State Electronics Facilities
Solid-state electronics equipment and facilities include (1) a modern integrated semiconductor device processing laboratory, (2) complete new Si and III-V compound molecular beam epitaxy systems, (3) CAD and mask-making facilities, (4) lasers for beam crystallization study, (5) thin film and characterization equipment, (6) deep-level transient spectroscopy instruments, (7) computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, (8) low-temperature facilities for material and device physics studies in cryogenic tem-
temperatures, (9) optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, (10) characterization equipment for high-speed devices, including (11) high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

Multidisciplinary Research Facilities

The department is also associated with several multidisciplinary research centers including

- California NanoSystems Institute (CNSI)
- Center for Embedded Networked Sensing (CENS)
- Center for High-Frequency Electronics (CHFE)
- Center for Nanoscience Innovation for Defense (CNID)
- Functional Engineered Nano Architectures Focus Center (FENA)
- Plasma Science and Technology Institute
- Western Institute for Nanoelectronics (WIN)

Faculty Groups and Laboratories

Department faculty members also lead a broad range of research groups and laboratories that cover a wide spectrum of specialties, including

- Adaptive Systems Laboratory (Sayeed)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomous Intelligent Networked Systems (Rubin)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Razavi)
- Complex Networks Group (Roychoudhury)
- Design Automation Laboratory (He)
- Device Research Laboratory (K. Wang)
- Digital Microwave Laboratory (E. Wang)
- Flight Systems Research Center (Balakrishnan)
- High-Performance Mixed Mode Circuit Design Group (Yang)
- High-Speed Electronics Laboratory (Chang)
- Image Communications Laboratory (Villasenor)
- Integrated Circuits and Systems Laboratory (Abidi)

- Laser-Plasma Group (Joshi)
- Microfabrication Laboratory (Judy)
- Microsystems Research Laboratory (Judy)
- Microwave Electronics Laboratory (Itoh)
- Millimeter Wave and Optoelectronics Laboratory (Fetterman)
- Nanoelectronics Research Center (Judy, Franz)
- Networked and Embedded Systems Laboratory (Srivastava)
- Neuroengineering Research Laboratory (Judy)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonovitch)
- Proactive MedIanet Laboratory (van der Schaar)
- Speech Processing and Auditory Perception Laboratory (Alwan)
- 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

* A.V. Balakrishnan, Ph.D. (USC, 1954)
Control and communications, flight systems applications

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

Panagiotis D. Christofides, Ph.D. (Minnesota, 1996)
Process modeling, dynamics and control, computational and applied mathematics

Babak Daneshmand, Ph.D. (UCLA, 1993)
Digital VLSI circuits: wireless communication systems, high-performance communications integrated circuits for wireless applications

Suhas Diggavi, 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 U., 1980)
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical


* Also Professor of Mathematics

Lei He, Ph.D. (UCLA, 1999)
Computer-aided design of VLSI circuits and systems, coarse-grain programmable systems and field programmable gate array (FPGA), high-performance interconnect modeling and design, power-efficient computer architectures and systems, numerical and combinatorial optimization

Tatsuo Itoh, Ph.D. (Illinois, Urbana, 1969)
Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas; photonic bandgap structures and meta materials applications; active integrated antennas, smart antennas; RF technologies for reconfigurable front-ends; sensors and transponders

Bahram Jalali, Ph.D. (Columbia U., 1989)
RF photonics, integrated optics, fiber optic integrated circuits

Laser fusion, laser acceleration of particles, nonlinear optics, high-power lasers, plasma physics

Jack W. Judy, Ph.D. (UC Berkeley, 1996)
Microelectromechanical systems (MEMS), micromachining, microsensors, microactuators, and microsystems, neuroengineering, neural-electronic interfaces, neuro-MEMS, implantable electronic systems, wireless telemetry, neural prostheses, and magnetism and magnetic materials

William J. Kaiser, Ph.D. (Wayne State, 1983)
Research and development of new microsensor and microinstrument technology for industry, science, and biomedical applications; development and applications of new atomic-resolution scanning probe microscopy methods for microelectronic device research

Alan Laub, Ph.D. (Minnesota, 1974)
Numerical linear algebra, numerical analysis, condition estimation, computer-aided control system design, high-performance computing

Jia-Ming Liu, Ph.D. (Harvard, 1982)
Nonlinear optics, ultrafast optics, laser chaos, semiconductor lasers, optoelectronics, photonic, nonlinear and ultrafast processes

Warren B. Mori, Ph.D. (UCLA, 1967)
Laser and charged particle beam-plasma interactions, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics

Scientific computing, applied mathematics

C. Kumar N. Patel, Ph.D. (Stanford, 1961)
Quantum electronics: nonlinear optics, photoacoustics in gases, liquids, and solids; ultra-low level detection of trace gases; chemical and toxic gas sensors

Gregory J. Pottie, Ph.D. (McMaster, 1988)
Communication systems and theory with applications to wireless sensor networks

Yahya 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 genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, 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
sizers, A/D and D/A converters, high-speed data communication circuits
Vivani P. Roychowdhury, Ph.D. (Stanford, 1989)
Models of computation including parallel and distributed processing systems, quantum computation and information processing, circuits and computing paradigms for nanoelectronic systems, molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity theory
Izhak Rubin, Ph.D. (Princeton, 1970)
Telecommunications and computer communications systems, network protocols, mobile wireless and multimedia IP networks, UAV-UGV-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering
Henry Samue1, 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 signal processing, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplay 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. (U.C. Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems
Oscar M. Staﬀeuldt, Ph.D. (UCLA, 1967)
Quantum electronics; I.R. lasers and nonlinear optics; solar cells; I.R. detectors
Lieven Vandenberghen, Ph.D. (Katholieke U., Leuven, Belgium, 1992)
Optimization in engineering and applications in signal and control, circuit design, and signal processing
Mhiea 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, MEMS and superlattices, microwave and millimeter electronics, quantum information
Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory and signal processing with particular interest in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and detection
Alan N. Willson, Jr., Ph.D. (Syracuse, 1967)
Theory and application of digital signal processing including VLSI implementations, digital ﬁlter design, nonlinear circuit theory
Jason C. Wo, 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, signal and array processing, machine learning, signal processing systems, VLSI and systolic algorithms
Professors Emeriti
Frederick G. Allen, Ph.D. (Harvard, 1956)
Semiconductor physics, solid-state devices, surface physics
Francis C. Chen, Ph.D. (Harvard, 1964)
Radio frequency plasma sources and diagnostics for semiconductor processing
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, nonconvex programming, applications of mathematical programming to engineering and economic systems
Rajeev Jain, Ph.D. (Katholieke U., Leuven, Belgium, 1984)
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 dynamical 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)
Analog 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-k dielectrics
Control systems, modeling and control of nonlinear distributed-parameter systems with applications to micro- opto-electromechanical systems, micro and nano manipulation systems, coordination and control of multiple microspacecraft in formation
*Donald M. Wiberg, Ph.D. (Caltech, 1965)
Identification and control, especially of aerospace, biomedical, mechanical, and nuclear processes, modeling and simulation of respiratory and cardiovascular systems
Jack Willis, B.Sc. (U. London, 1945)
Active circuits, electronic systems
Associate Professors
Mark H. Hansen, Ph.D. (UC Berkeley, 1994)
Estimation and inference, statistical learning, data analysis; model selection, nonparametric methods; visualization and information design
Diana L. Huffaker, Ph.D. (Texas, Austin, 1995)
Solid-state nanotechnology, MWIR optoelectronic devices, solar cells, Si photonics, novel materials
Yuanxun 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, micro-wave integrated circuits
Assistant Professors
Danijela Cabrca, Ph.D. (UC Berkeley, 2007)
Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and 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 sensing
Chi On Chui, Ph.D. (Stanford, 2004)
Nano-electronic and optoelectronic devices and technology, heterostructure semiconductor devices, monolithic integration of heterogeneous technology, exploratory nanotechnology
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
Puneet Gupta, Ph.D. (UC San Diego, 2007)
CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing
Jin Hyung Lee, Ph.D. (Stanford, 2004)
Advanced imaging techniques for biomedical applications; neurosciences and neural-engineering; magnetic resonance imaging (MRI); development of novel image contrast strategies; alternate image acquisition, reconstruction, and processing techniques
Dejan Markovic, Ph.D. (UC Berkeley, 2006)
Power/area efﬁcient digital integrated circuits, VLSI architectures for wireless communications, organization methods and supporting CAD tools
Christoph Niemann, Ph.D. (U. Technology, Darmstadt, Germany, 2002)
Plasma physics in the context of thermonuclear fusion, laser and charged particle beam-plasma interaction, high-energy density science, plasma- and particle-beam diagnostics
Aydogan Ozcan, Ph.D. (Stanford, 2005)
Bioimaging, nano-photonic, nonlinear optics
Sudhakar Pamarti, Ph.D. (UC San Diego, 2003)
Mixed-signal IC design, signal processing and communication theory
Paulo Tabuada, Ph.D. (Technical University of Lisbon, Portugal, 2002)
Real-time, networked, embedded control systems; mathematical systems theory including discrete-event, timed, and hybrid systems; geometric nonlinear control; algebraic categorical methods
Benjamin Williams, Ph.D. (MIT, 2003)
Development of terahertz quantum cascade lasers
Adjunct Professors
Ezio Biglieri, Dr. Ing. (Politecnico di Torino, Italy, 1967)
Digital communication, wireless channels, modulation, error-control coding, signal processing in telecommunications
Mary Eshagian-Wilner, Ph.D. (USC, 1998)
Nanoscale architectures, bioinformatics networks, heterogeneous computing, mapping and scheduling paradigms, optical interconnects, VLSI and reconfigurable chips, parallel algorithms for image processing
Michael P. Fitz, Ph.D. (USC, 1989)
Physical layer communication theory and implementation with applications in wireless systems
Joel Schulman, Ph.D. (Caltech, 1979)
Semiconductor super lattices, solid-state physics
Lower Division Courses

1. Electrical Engineering Physics I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 32A, 32B, Physics 1A, 1B. Introduction to modern physics and electromagnetism with engineering orientation. Emphasis on mathematical tools necessary to express and solve Maxwell equations. Relation of these concepts to waves propagating in free space, including dielectrics and optical systems. Letter grading.

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

3. Introduction to Electrical Engineering. (2) Lecture, two hours. Introduction to field of electrical engineering; research and applications across several areas, such as communications, control, electromagnetics, embedded computing, optimization, integrated circuits, MEMS, nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. P/NP grading.


Mr. Abidi, Mr. Gupta (F,SP)

M16. Logic Design of Digital Systems. (4) (Same as Computer Science M51A.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.

Ms. Cabric, Mr. He (F, W, SP)

19. Flat Lux Freshman Seminars. (1) Seminar. 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 academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Prerequisite: course 1 or Physics 1C. Mathematics 33A, 33B. Electronic 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. Razaee (F,SP)

101. Engineering Electromagnetics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Prerequisite: Mathematics 33A, 33B. Electromagnetic field concepts, waves and phasors, transmission lines and Smith chart, transient responses, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading.

Mr. Ozcan, Mr. Williams (F, W)


Mr. Tran, Ms. Lee (F, SP)


Mr. Meghavan, Mr. Vandenberghe (F,SP)

110. Circuit Analysis II. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 10. Corequisite: course 102. Sinusoidal excitation and phasors, AC steady state analysis, AC steady state functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis. Letter grading.

Mr. Pamarti, Mr. Willson (F, W)

110L. Circuit Measurements Laboratory. (2) Laboratory, four hours; outside study, two hours. Requisite: course 100 or 110. Experiments with basic circuits containing resistors, capacitors, inductors, and op-amps. Ohm’s law, voltage and current division, Thévenin and Norton equivalent circuits, superposition, transient and steady state analysis, and frequency response principles. Letter grading.

Mr. Razaee (F, SP)


Ms. Alwan, Ms. van der Schaaf (F, SP)

113D. Digital Signal Processing Design. (4) Laboratory, four hours; outside study, four hours. Requisite: course 113. Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments involving A/D and D/A conversion, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing algorithms with communication, speech, audio, or video using DSP chip. Letter grading.

Mr. Daneshrad (F, W, SP)

114. Speech and Image Processing Systems Design. (4) Formerly numbered 114D.) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Requisite: course 113. Design principles of speech and image processing systems. Speech production, analysis, and modeling in first half of course; design of speech and image encoding, enhancement, filtering, and transformation in second half. Lectures supplemented by laboratory implementation of speech and image processing tasks. Letter grading.

Mr. Vilenius (W)


Mr. Daneshrad (F, W, SP)

115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. Requisites: courses 110L, 115A. Experimental determination of the characteristics of bipolar and MOS devices, single-stage amplifiers, compound transistor stages, effect of feedback on single-stage amplifiers. Letter grading.

Mr. Babaie, Mr. Kaiser (F, W, SP)

115B. Analog Electronic Circuits II. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 115A. Analysis and design of differential amplifiers in bipolar and CMOS technologies. Current mirrors and active loads. Frequency response of amplifiers, models, and their properties. Stability issues and frequency compensation. Letter grading.

Mr. Razaee (F, W)

115BL. Analog Electronics Laboratory II. (4) Laboratory, four hours; outside study, eight hours. Requisites: courses 115AL, 115B. Experimental and computer studies of multistage, wideband, tuned, and power amplifiers, and multistage feedback amplifiers. Introduction to thick film hybrid techniques. Construction of amplifiers using hybrid thick film techniques. Letter grading.

Mr. Razaee (SP)

115C. Digital Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 110, 115A. Recommended: course 115B. Transistor-level digital circuit analysis and design. Modern logic families (static CMOS, pass-transistor, dynamic logic), integrated circuit (IC) layout, digital circuits (logic gates, flip-flops, counters, flip-flops), computer-aided simulation of digital circuits. Letter grading.

Mr. Markovic, Mr. Pamarthi (W)


Mr. Abdi (SP)


Mr. Gupta (F, W)
M116L. Introductory Digital Design Laboratory. (2) (Same as Computer Science M152A.) Laboratory, four hours outside study; two hours. Requisites: 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, implementation of complex digital systems and design of memory array logic, design projects. Letter grading. Mr. He (F,W,Sp)

M117. Computer Networks: Physical Layer. (4) (Same as Computer Science 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 computer 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 (e.g., Bluetooth, ZigBee). Experimental laboratory sessions included. Letter grading.

Mr. Gerla (W,Sp)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, two hours. Requisite: course 2. Introduction to principles of operation of bipolar and MOS transistors, equivalent circuits, high-frequency behavior, voltage limitations. Letter grading.

Mr. Chui, Mr. Woo (W,Sp)

122L. Semiconductor Devices Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: courses 2, 121B (may be taken concurrently). Design fabrication and characterization of p-n junctions and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Letter grading. (Lab only: Mr. Candler (Sp))

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 2 or Physics 1C. Limited to junior/senior engineering majors. Fundamentals of 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.

Mr. Candler (F)

123B. Fundamentals of Solid-State II. (4) Lecture, three hours; outside study, nine hours. Requisite: course 123A. Discussion of solid-state properties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties of solids and semiconductors.

Ms. Huffaker (W)

124. Semiconductor Physical Electronics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 123A. Band structure, semiconductor experimental probes of basic band structure parameters, statistics of carriers, carrier transport properties at low fields, excess carrier transport properties, carrier recombination mechanisms, heterojunction properties. Letter grading. (Not offered 2010-11)

128. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisites: course 1, or Physics 1A and 1B. Introduction to fundamentals of nanoscience for electronics nanosystems. Principles of fundamental quantities: electron charge, effective mass, Bohr magneton, and spin, as well as theoretical approaches. From these nanoscale components, discussion of basic behaviors of nanosystems such as analysis of dynamics, variability, and noise, contrasted with those of scaled CMOS. Incorporation of design projects in which students are challenged to design electronic nanosystems. Letter grading.

Mr. K.L. Wang (W)

129D. Semiconductor Processing and Device Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisite: course 121B. Introduction to CAD tools used in integrated circuit process and device design. Device structure optimization to control device characteristics; process integration tool is based on SUPREM. Course familiarizes 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, 10 hours. Requisites: course 102, Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables, probability distribution functions, densities, moments, characteristic functions, and limit theorems. Applications to communication, control, and signal processing. Introduction to computer simulation and evaluation of random events. Letter grading.

Mr. Dolecek, Mr. Yao (F,W)

131B. Introduction to Stochastic Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Introduction to basic 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 (Sp)


Mr. Pottie, Mr. Villasenor (W,Sp)


(Not offered 2010-11)


Mr. Roychowdhury, Mr. Tabuada (W,Sp)

142. Linear Systems: State-Space Approach. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. 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. Balakrishnan (W)

CM150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Biomedical Engineering CM150L and Mechanical and Aerospace Engineering CM180L.) Lecture, one hour; laboratory, four hours; outside study, eight hours. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250L. Letter grading.

Mr. Candler (F)

150DL. Photonic Sensor Design Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, eight hours. Limited to seniors. Multidisciplinary course with lectures and laboratory experiments on optical sensors. Fundamentals of intensity and interference-based transducers, polarimeters, microsensors, and sensor networks with biomedical sensors. Design and implementation of optical gyroscope, computer interfacing, and signal processing. Letter grading. (Not offered 2010-11)

CM150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Biomedical Engineering CM150L and Mechanical and Aerospace Engineering CM180L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: Chemistry 20A, 20B, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course CM150. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Design and fabrication 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 CM250L. Letter grading.

Mr. Candler (F)

161. Electromagnetic Waves. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101. Time-varying fields and Maxwell equations, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides and resonant cavity, group velocity, radiation and antennas. Letter grading.

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

162A. Wireless Communication Links and Antennas. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 161. Basic properties of transmitting and receiving antennas and antenna arrays. Adaptive arrays. Friis transmission formula, radar equations. Cell-site and mobile antennas, basic system design in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and shadowing effects, shadowing phenomena. Letter grading. Mr. Rahmat-Samii (Sp)

163A. Introductory Microwave Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 161. Transmission line description of waveguides, impedance transformers, power dividers, directional couplers, filters, hybrid junctions, nonreciprocal devices. Letter grading.

Mr. Y.E. Wang (W)

163B. Microwave and Millimeter Wave Active Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 121B. MESFET, HEMT, HBT, IMPATT, Gunn, small signal microwave amplifiers and oscillators, parameter extraction techniques, parameter extraction technique. Letter grading. (Not offered 2010-11)

163C. Active Microwave Circuits. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 115A, 161. Theory and design of microwave transistor amplifiers and oscillators; stability, noise, distortion. Letter grading.

Mr. Y.E. Wang (W)

164D. Microwave Wireless Design. (4) Lecture, one hour; laboratory, four hours; outside study, seven hours. Requisite: course 161. Microwave integrated circuit design from wireless system perspective, with focus on (1) use of microwave circuit simulation tools, (2) design of wireless frontend circuits including low noise amplifier, mixer, and power amplifier, (3) knowl-
164L. Microwave Wireless Laboratory. (2) Lecture, one hour; laboratory, three hours; outside study, three hours. Requisite: course 161. Measurement techniques and instrumentation for active and passive microwave components; cavity resonators, waveguides, wave meters, slotted lines, directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip and coaxial systems. Letter grading. Prerequisites: course 161L. (Sp)

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. Introduction 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 in experiments on pulse transmission through waveguides and the transmission of signals through modem and terminal characteristics, and interfaces. Letter grading. Mr. Fetterman (FW,SP)

172. Introduction to Lasers and Quantum Electronics. (2) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 101. Physical applications and principles of lasers, Gaussian optics, resonant cavities, atomic radiation, laser oscillation and amplification, cw and pulsed lasers. Letter grading. Mr. Jalali, Mr. Williams (FSp)

172L. Laser Laboratory. (4) Laboratory, four hours; outside study, eight hours. Requisite or corequisite: course 172. Properties of lasers, including saturation, gain, mode structure. Laser applications, including optics, modulation, communication, holography, and interferometry. Letter grading. Mr. Stafsudd (FSp)

173. Photonic Devices. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101. Introduction to basic principles of photonic devices. Topics include crystal optics, dielectrics, optical waveguides, waveguide couplers, electro-optic devices, magneto-optic devices, acoustooptic devices, second-harmonic generation, optical Kerr effect, optical switching devices. Letter grading. Mr. Liu (W)

173D. Photonics and Communication Design. (4) Lecture, four hours; outside study, eight hours. Requisite site: course 102. Recommended: course 132A. Introduction to measurement of basic photonic devices, including LEDs, lasers, detectors, and amplifiers; fiber-optic communication systems, modulation techniques, including AM, FM, phase and suppressed carrier methods. Letter grading. Mr. Stafsudd (FSp)

174. Semiconductor Optoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 172. Introduction to semiconductor optoelectronic devices for optical communications, interconnects, and signal processing. Basic optical properties of semiconductors, pin photodiodes, avalanche photodiode detectors (APD), light-emitting diodes (LED), semiconductor lasers, optical modulators and amplifiers, and typical photonic systems. Letter grading. (Not offered 2010-11)

175. Fourier Optics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: courses 102, 161. Two-dimensional linear systems and Fourier transforms. Foundation of diffraction and imaging systems. Differentiation. Spatial filtering and optical information processing. Wavefront reconstruction and holography. Letter grading. (Not offered 2010-11)

176. Lasers in Biomedical Applications. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 101. Study of different types of laser systems and their operation. Examination of their roles in current and projected biomedical applications. Specific capabilities of laser radiation to be related to each example. Letter grading. Mr. He (F)

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

181D. Robotic Systems Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses M16, 110L, M16L (or Computer Science M152A), Computer Science 31, 33. Recommended: courses 113, 141, Computer Science 35L. Design of robotics systems that combine embedded hardware, software, mechanical subsystems, and fundamental algorithms for sensing and control to express students to basic concepts, and current state of art. Lecture closely tied to design laboratory where students work in teams to construct series of subsystems leading to final project. Letter grading. Mr. Srivastava (F)

184DA-184DB. Independent Group Project Design. (2-2) (Formerly numbered 184D.) Laboratory, five hours; discussion, one hour. Requisites: courses M16, 110L, M16L is required. Letter grading. Courses centered on group project that runs year long to give students intensive experience on hardware design, microcontroller programming, and project coordination. Several projects based on autonomous robots that traverse small mazes and games offered yearly and target regional competitions. Students may submit proposals that are evaluated and approved by faculty. Topics include sensing circuits and amplifier-based design, microcontroller programming, feedback control, actuation, and motor control. In Progress (184DA) and letter (184DB). Mr. Srivastava (W)

184M185. Introduction to Plasma Electronics. (4) (Same as Physics M122.) Lecture, three hours. Requisite: course 101 or Physics 110A. Senior-level introductory course on electrodynamics of ionized gases and applications to materials processing, generation of coherent radiation and particle beams, and renewable energy sources. Letter grading. Mr. Mori (F; even years)

183. Special Topics in Electrical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in electrical engineering for undergraduates. Students taught on experimental or temporary or credit. Letter grading. (Not offered 2010-11)

184A-184B. Modeling of VLSI Circuits and Systems. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Limited to graduate students. Application of techniques of graduate-level topics. Letter grading. Mr. Laub (F)

201C. Modeling of VLSI Circuits and Systems. (4) Lecture, four hours; required course 115C. Detailed study of VLSI circuit and system models concerning performance, signal integrity, power and thermal effects, reliability, and manufacturability. Discussion of principles of modeling and optimization codevelopment. Letter grading. Mr. He (W)

M202A. Embedded Systems. (4) (Same as Computer Science M213A.) Lecture, four hours; outside study, eight hours. Designed for graduate computer science and electrical engineering students. Methodologies and technologies for embedded systems. Topics include hardware and software platforms for embedded systems, techniques for model and specification of system behavior, software organization, real-time operating systems, real-time communication and packet scheduling, low-power battery and energy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Theoretical foundations as well as practical design methods. Letter grading. Mr. Srivastava (F)

M202B. Distributed Embedded Systems. (4) (Same as Computer Science 132B.) Lecture, four hours; outside study, eight hours. Requisites: course 132B or Computer Science 118, and Computer Science 111. Designed for graduate computer science and electrical engineering students. The course with focus on distributed embedded systems concepts needed to realize systems such as wireless sensor and actuator networks for monitoring and control of physical systems. In addition, integration of embedded hardware with the network self-configuration with localization and timing synchronization; energy-aware system design and operation; protocols for MAC, routing, transport, disruption tolerant; programming models with language, OS, database, and middleware; in-network collaborative processing; fundamental characteristics such as coverage, connectivity, capacity, latency; techniques for exploitation of energy-aware aspects of actuation and mobility; data and system integrity issues with calibration, faults, debugging, and security; and usage issues such as human interfaces and safety. Letter grading. (Not offered 2010-11)

202C. Networked Embedded Systems Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Designed for graduate computer science and electrical engineering students. Training in combination of networked embedded systems design combining embedded hardware platform, embedded operating system, and hardware/software interconnection. Potential graduate studies include PhD research and industry career paths in wireless devices for applications ranging from conventional wireless mobile devices to new area of wireless health. Lab: design and development of course projects based on state-of-art embedded hardware platform. Letter grading. Mr. Kaiser (W)

205A. Matrix Analysis for Scientists and Engineers. (4) Lecture, four hours; outside study, eight hours. Preparation: one undergraduate linear algebra course. Designed for first-year graduate students in all branches of engineering, science, and related disciplines. Introduction to matrix theory and linear algebra, language in which virtually all engineering science and engineering is conducted. Review of matrices taught in undergraduate courses and introduction to graduate-level topics. Letter grading. Mr. Laub (F)

M208B. Functional Analysis for Applied Mathematics and Engineering. (4) (Same as Mathematics M208B.) Lecture, four hours; outside study, eight hours. Requisites: courses 208A (or Mathematics 115A and 115B), Mathematics 131A, 131B, 132. Topics may include L^p spaces, Hilbert, Banach, and separable spaces; Fourier transforms; linear functionals, inner product spaces, linear operators and their adjoints; self-adjoint and compact operators. Spectral theory. Differential operators such as Laplace, Dirichlet conditions, and Green's functions. Semigroups. Applications. S/U or letter grading. (Not offered 2010-11)

M208C. Topics in Functional Analysis for Applied Mathematics and Engineering. (4) (Formerly numbered 208C.) Lecture, four hours; outside study, eight hours. Special topics. May be repeated for credit. Credit/No Credit grading.

M209AS. Special Topics in Circuits and Embedded Systems. (4) Lecture, four hours; outside study, eight hours. Special topics. May be repeated for credit. Credit/No Credit grading.

M209BS. Seminar: Circuits and Embedded Systems. (2 to 4) Seminar, two to four hours; outside study, eight hours. Seminar in various aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication systems; embedded processor architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. I, II, III, IV

Ms. Cabric, Mr. Chang, Mr. Gupta (F, W, Sp)

M210. Adaptive Filtering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131B. Mathematical principles and theorems on recent research and advanced topics in one or more aspects of circuits and embedded systems, such as digital, analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication systems; embedded processor architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U grading. (Not offered 2010-11)


211A. Digital Image Processing I. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Preparation: computer programming experience. Requisite: course 113. Fundamentals of digital image processing techniques. Topics include two-dimensional linear system theory, image transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading. Mr. Villasenor (F)

211B. Digital Image Processing II. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Requisites: course 208A or Mathematics 115A and 115B, Mathematics 131A, 131B, 132. Topics may include modeling, restoration, still-frame and video image compression, tomographic imaging, and multi-resolution analysis using wavelet transforms. Letter grading. (Not offered 2010-11)


212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems; polyphase representation; multirate implementations; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; parainty filter banks; wavelet transform and its relation to multirate filter banks. Letter grading. Mr. Willson (Sp)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, four hours; outside study, nine hours. Requisite: course 212A. Sampled-data filter design methods and optimization techniques, 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 2010-11)

M214A. Digital Speech Processing. (4) (Same as Biomedical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 113. Theory and applications of digital processing of speech signals. Mathematical models of human speech production and perception mechanisms, speech analysis/synthesis. Techniques include linear prediction, filter-bank models, and homomorphic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Ms. Alwan (W)

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

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 bipoles, device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and systems, and bang-bang references. Letter grading. Mr. Razavi (F)


215C. Analysis and Design of RF Circuits and Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 215A. Principles of RF circuit and system design, with emphasis on monolithic implementation in VLSI technologies. Basic concepts, common signal background, transmitter architecture, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading. Mr. Abov (W)

215D. Analog Microsystem Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 215A. Analysis and design of data conversion interfaces and filters. Sampling circuits and architecture design for analog microsystems. Letter grading. Mr. Razavi (Sp)

215E. Signaling and Synchronization. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 212A and 215D. Advanced digital and analog design techniques to improve data rate of electronics between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading. Mr. Pampati (Sp)

M216A. Design of VLSI Circuits and Systems. (4) (Same as Computer Science M258A.) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisite: course M161 or Computer Science M51A, and 115A. Recommended: course 115C. LSIVLSI design and application in computer systems. Design techniques that can be used to implement complex integrated systems on chips. Letter grading. Ms. Markovic (F)

215B. VLSI Signal Processing. (4) Lecture, four hours; outside study, eight hours. Advanced concepts in VLSI signal processing, with emphasis on architecture design and optimization within block-based description that can be mapped to hardware. Fundamental concepts from digital signal processing (DSP) theory, architecture, and circuit design applied to complex DSP algorithms in emerging applications for personal communications and healthcare. Letter grading. (Not offered 2010-11)

M217. Biomedical Imaging. (4) (Same as Biomedical Engineering M217.) Lecture, four hours; outside study, nine hours. Requisite: course 114 or 211A. Optical imaging modalities in biomedicine. Other non-optical imaging modalities discussed briefly for comparative purposes. Letter grading. Mr. Özcan (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 of several existing multiagent learning techniques that can be successfully deployed in multi-agent systems. Letter grading. Ms. van der Schara (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. Ms. He (W)

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. Woo (W)
221C. Microwave Semiconductor Devices. (4) Lecture, four hours; outside study, eight hours. Physical processes, design considerations. Microwave 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 Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220C. Principles of integrated circuits fabrication processes. Technological limitations of integrated circuit design. Topics include bulk carrier diffusion and epitaxial growth, thermal oxidation, diffusion, ion-implantation, chemical vapor deposition, dry etching, lithography, and metallization. Introduction of advanced process simulation tools. Letter grading. Mr. Chui (F).


225. Physics of Semiconductor Nanostructures and Devices. (4) Lecture, four hours; outside study, eight hours. Prerequisite: course 223. Theoretical methods for calculating electronic and optical 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. Huffaker (Sp, alternate years).

226. Seminar: Advanced Topics in Solid-State Electronics. (4) Seminar, four hours; outside study, eight hours. Preparation for comprehensive examination. 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 2010-11)

229S. Advanced Electrical Engineering Seminar. (2) Seminar, two hours; outside study, six hours. Preparation for comprehensive examination. Two-hour field examination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on tutorial topic and on research topic seminar paper. May be repeated for credit. S/U grading. (Not offered 2010-11)

230A. Estimation and Detection in Communication and Radar Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Applications of estimation and detection concepts in communication and radar engineering; random signal and noise characteristics by analytical and simulation methods; mean square (MS) and maximum likelihood (ML) estimation and algorithms; detection under ML, Bayes, mean square (MS) and maximum likelihood (ML) estimation algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading. Ms. Dolecek (W).

230B. Digital Communication Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 232A, 230A. Basic concepts of digital communication systems: modulation, demodulation, bandwidth, 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. Mr. Yao (F).


232A. Stochastic Modeling with Applications to Telecommunication Systems. (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 versus distortion in lossy compression, and information theory for multiple users. Letter grading. Ms. Dolecek (W).

232B. Telecommunication Switching and Queueing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Introduction to stochastic processes as applied to study of telecommunication systems and traffic engineering. Renewal theory; discrete-time Markov chains; continuous-time Markov jump processes. Applications to traffic and queueing analysis of basic telecommunication system models. Letter grading. (Not offered 2010-11)

232B. Telecommunication Switching and Queueing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Introduction to stochastic processes as applied to study of telecommunication systems and traffic engineering. Renewal theory; discrete-time Markov chains; continuous-time Markov jump processes. Applications to traffic and queueing analysis of basic telecommunication system models. Letter grading. (Not offered 2010-11)

232D. Telecommunication Networks and Multiple-Access Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Analysis and design of integrated-service telecommunication networks and multiple-access procedures. Stochastic analysis of priority-based queueing systems, bandwidth-sharing networks; network protocol architectures; error control; routing, flow, and access control. Applications to local-area, packet-radio, satellite, and computer communication networks. Letter grading. (Not offered 2010-11)

232E. Graphs and Network Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 136. Solution to analysis and synthesis problems that may be formulated as flow problems in capacity constrained (or cost constrained) networks. Development of tools of network flow theory using graph theoretic methods; application to communication, transportation, and transmission problems. Letter grading. Ms. van der Schaar (F).

233. Wireless Communications Systems. (4) (Formerly numbered 233B.) Lecture, four hours; outside study, eight hours. Requisite: course 232B. 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, multiple-access schemes, transceiver design and effects of non-ideal components, hardware partitioning issues. Course study highlights system level tradeoffs. Letter grading. Mr. Pottie (Sp).


237. Dynamic Programming. (4) (Same as Mechanical and Aerospace Engineering M276.) Lecture, four hours; outside study, eight hours. Recommended prerequisite: course 232A. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon models. Methods of solution: inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. (Not offered 2010-11)

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 and low-cost infrastructure, new networks and communication channels enable variety of delay-sensitive multimedia transmission applications and provide varying resources with limited support for quality of service required by delay-sensitive, bandwidth-intensive, and loss-tolerant multimedia applications. New concepts, principles, theories, and practical solutions for cross-layer design that can provide optimal adaptation for time-varying channel characteristics, adaptive and delay-sensitive applications, and multimedia transmission environments. Letter grading. Ms. van der Schaar (F).

239S. Special Topics in Signals and Systems. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more areas of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, tele-
communications, and VLSI signal processing. May be repeated for credit with topic change. S/U or letter grading.

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 communications, computer networking, digital image processing, information theory, multimedia, automatic control, communication, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U grading.

M240A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M260A and Mechanical and Aerospace Engineering M270A.) 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, 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. Tabuada (F)

240B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 141, M240A. Introduction to optimal control, with emphasis on detailed study of LQR, or linear regulators with quadratic cost criteria. Requirement to classical control system design. Letter grading.

(Not offered 2010-11)

M240C. Optimal Control. (Same as Chemical Engineering M260C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisite: course 240B. Applications of variational methods, Pontryagin maximum principle. Applications to real systems, optimal control by dynamic programming to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading.

(Not offered 2010-11)


Mr. Diggavi (F)

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 systems; discrete-time state-space models; sigma algebra equivalence and separation principle; dynamic programming; compensator design for time invariant systems; feedback control and servomechanisms, extensions to nonlinear systems; applications; introduction to maximum variance control. Letter grading.

(Not offered 2010-11)


(Not offered 2010-11)

243. Robust and Optimal Control by Convex Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: course M240A. Multivariable robust control, including H2 and H-Infinity optimal control and robust control analysis and synthesis against structured uncertainty. Emphasis on convex methods for analysis and design, in particular linear matrix inequality (LMI) approach to control. Letter grading.

Mr. Judy (Sp)

M254. Nonlinear Systems. (2 to 4) Seminar, four hours; outside study, eight hours. Requisite: course M245A. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading.

Mr. Judy (Sp)

M255. Neuroengineering. (4) (Same as Biomedical Engineering M260 and Neuroscience M206.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 2B. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and analysis. Topics include bioelectricity, electrophysiology (action potentials, local field potentials, EEG, ECOG), intracellular and extracellular recording, microelectrode technology, neural signal recording (neural probe, intracranial recording, data transfer), signal processing (filtering, spike detection, spike sorting, stimulation 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 Biomedical Engineering M240 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.

257. Nanoscience and Technology. (4) (Same as Mechanical and Aerospace Engineering M257.) Lecture, four hours; outside study, eight hours. 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; nanomaterials, nanoelectronics, and nanobiodetection technology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading.

Mr. Chen (W)

260A. Advanced Engineering Electrodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 161, 162A. Advanced treatment of concepts in electrodynamics and their applications to electromagnetic problems. Advanced topics such as plasma, inhomogeneous, and dispersive media. Guided waves in bounded and unbounded regions. Radiation and diffraction, including optical phenomena. Partially coherent waves, statistical methods. Letter grading.

Mr. Rahmat-Samii (F)


Mr. Rahmat-Samii (W)

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, including eigenmode (MMS) analysis of microwave and millimeter wave circuits. Letter grading.

Mr. Itoh (W)


(Not offered 2010-11)


Mr. Itoh (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 courses. Principles of quantum mechanics for applications in lasers, solid-state and optical physics. Topics include eigenfunction expansions, observables, Schrödinger equation, uncertainty principle, central force problems, Hilbert spaces, WKB approximation, matrix mechanics, density matrix formalism, and radiation theory. Lec. 4; HW 1; Lab 1. Mr. Williams (Sp).


274. Fiber Optic System Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 173D and/or 174. Top-down introduction to physical layer design in fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-aided design. Architectural-level design of fiber optic transceiver circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading. Mr. Jalali (F).

279AS. Special Topics in Physical and Wave Electronics. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U or letter grading. Mr. Joshi (Sp).

279BS. Seminar: Physical and Wave Electronics. (2 to 4) Seminar, two to four hours; outside study, four hours. Seminars and discussions on current and advanced topics in one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. (Not offered 2010-11)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and streaming instabilities. Application to experiments in fully and partially ionized plasmas. Letter grading. (Not offered 2010-11)

285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M185, and 285A or Physics M222A. 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 2010-11)


295. Technical Writing for Electrical Engineers. (2) Lecture, two hours. Designed for electrical engineering Ph.D. students. Opportunity for students to improve technical writing skills by revising conference, technical, and journal papers and practicing writing about their work for undergraduate audience (potential students), engineers outside their specific fields, and nonscientists (colleagues with less expertise in field and policymakers). Students write in variety of genres, all related to their professional development as electrical engineers. Emphasis on writing as vital way to communicate precise technical and professional information in distinct contexts, directly resulting in successful outcomes in specific S/U grading. Ms. Alwan (F,Sp).

296. Seminar: Research Topics in Electrical Engineering. (2) Seminar, two hours, outside study, four hours. Advanced study and analysis of current topics in electrical engineering. Discussion of current research and literature in research specialty of faculty member teaching course. May be repeated for credit. S/U grading.

297. Seminar Series: Electrical Engineering. (1) Seminar, 90 minutes; outside study, 90 minutes. Limited to graduate electrical engineering students. Weekly seminars and discussion by invited speakers on research topics of heightened interest. S/U grading.

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate electrical engineering students. May be arranged for credit and analysis of current technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. S/U or letter grading. (Not offered 2010-11)

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. 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)


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.
At the heart of materials science is an understanding of the microstructure of solids. Microstructure is used broadly in reference to solids viewed at the subatomic (electronic) and atomic levels, and the nature of the defects at these levels. The microstructure of solids at various levels profoundly influences the mechanical, electronic, chemical, and biological properties of solids. The phenomenological and mechanistic relationships between microstructure and the macroscopic properties of solids are, in essence, what materials science is all about.

Materials engineering builds on the foundation of materials science and is concerned with the design, fabrication, and optimal selection of engineering materials that must simultaneously fulfill dimensional, property, quality control, and economic requirements.

The department also has a program in electronic materials that provides a broad-based background in materials science, with opportunity to specialize in the study of those materials used for electronic and optoelectronic applications. The program incorporates several courses in electrical engineering in addition to those in the materials science curriculum.

The undergraduate program leads to the B.S. degree in Materials Engineering. Students are introduced to the basic principles of metallurgy and ceramic and polymer science as part of the department's Materials Engineering major.

A joint major field, Chemistry/Materials Science, is offered to students enrolled in the Department of Chemistry and Biochemistry (College of Letters and Science). The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

**Department Mission**

The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

**Undergraduate Program Objectives**

The Materials Engineering 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 B.S. Capstone Major**

The ABET-accredited materials engineering program is designed for students who wish to pursue a professional career in the materials field and desire a broad understanding of the relationship between microstructure and properties of materials. Metals, ceramics, and polymers, as well as the design, fabrication, and testing of metallic and other materials such as oxides, glasses, and fiber-reinforced...
composites, are included in the course contents.

Materials Engineering Option

Preparation for the Major

**Required:** Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1).

The Major

**Required:** Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Electrical Engineering 101, 121B, Materials Science and Engineering 104, 110, 110L, 120 (or Electrical Engineering 2), 121, 121L, 122, 130, 131, 131L, 132, 143A, 150, 160, Mechanical and Aerospace Engineering 181A or 182A; two laboratory courses (4 units) from Materials Science and Engineering 121L, 141L, 143L, 161L; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and one major field elective course (4 units) from Electrical Engineering 110, 124, 131A, 172, Materials Science and Engineering 111, 143A, 162.

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

Graduate Study

For information on graduate admission, see Graduate Programs, page 23. The following introductory information is based on the 2010-11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www.gdnet.ucla.edu/gasasa/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 586 (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 111, 121, 122, 143A, 151, 161, 162, 200, 201, 211, 246D, 298.

Electronic and optical materials: Materials Science and Engineering 111, 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, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Thesis Plan

In addition to fulfilling the course requirements, 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 written preliminary examination requirements. 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 students’ 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 Materials Science and Engineering Department at UCLA. One outside member must be a UCLA faculty member outside the Materials Science and Engineering Department. Faculty members holding joint appointments with the department are considered inside members.

Fields of Study

Ceramics and Ceramic Processing
The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials
The electronic and optical materials field provides an area of study in the science and technology of electronic materials that includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanoscale properties and devices in materials science.

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:

ï Ceramic Processing Laboratory
ï 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 analysis, a stereo microscope, micro-camera, and metallurgical microscopes
ï Glass and Ceramics Research Laboratories
ï Mechanical Testing Laboratory
ï Metallographic Sample Preparation Laboratory
ï Nano-Materials Laboratory
ï Nondestructive Testing Laboratory
ï Organic Electronic Materials Processing Laboratory
ï Semiconductor and Optical Characterization Laboratory
ï Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonders
ï X-Ray Diffraction Laboratory
ï X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors
Russell E. Caflisch, Ph.D. (New York U., 1978) Theory and numerical simulation for materials physics, epitaxial growth, nanoscale systems, semiconductor device properties and design in applications to quantum well devices, quantum dots, nanocrystals and quantum computing
The research efforts of professor Suneel Kodambaka’s In situ Microscopy Lab are focused on synthesis and characterization of low-dimensional structures such as quantum dots, nanowires, and graphene thin films. Research students include (left to right) Dean Cheikh, Jeung Hun Park, Chilan Ngo, Filiberto Colon, and Yuya Murata.
Applications of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes, etc. under simple and combined loading, strain rate sensitivity, microstructural control and evolution of microstructures and new materials. The properties of materials science and engineering. Development of new materials for optoelectronic devices and characteristics, including optical, electrical, and magnetooptic properties. The structure and properties of materials for applications in engineering, Letter grading. Mr. Dunn (F/W/Sp)

M105. Principles of Nanoscience and Nanotechnology. (4) Same as Engineering M101L. Lec- ture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20, and Electrical Engineering 1 or Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in nanoscale systems and their state of preservation. Theoretical and hands-on instruction to provide fundamentals of portable/field and analytical techniques such as UV/VNIR spectrophotometry, X-ray fluorescence (XRF), X-ray diffraction (XRD), scanning electron microscopy and energy dispersive spectroscopy (SEM-EDS), and others. Examination and analysis protocols, sample preparation techniques, and methods of scientific analysis and interpretation for study of organic and inorganic materials of archaeological and cultural significance. Concurrently scheduled with course CM212. Letter grading.

120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 110 (or Chemistry 113A). Introduction to 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 charac- terization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading. Mr. Y. Yang (W)

121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 120. Structure and properties of elemental and compound semiconduc- tors. Electrical and optical properties, defect chemistry, and doping. Electron and holes analysis and characterization, including electrical, optical, and ion-beam techniques. Heterostructures, band-gap engineering, development of new materials for opto- electronic applications. Letter grading. Ms. Huang (Sp)

121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 min- utes; laboratory, two hours; outside study, three hours. Corequisite: course 121. Experiments con- ducted on materials characterization, including mea-
structural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading.

Mr. Przystupa (Sp, even years)

143L. Mechanical Behavior Laboratory. (2) Laboratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Methods of characterizing mechanical behavior of various materials; elasticity and plasticity, 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 crystallinity, and morphology and their effects on physical properties. Glassy polymers, springy polymers, elastomers, adhesives. Fiber forming, processing techniques and association.

Letter grading.

Mr. Pei (W)


Mr. J-M. Yang (Sp)

160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, ten hours. Requisites: courses 104 and 105. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading.

Mr. Dunn (F)


Mr. Dunn


Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, six hours. Requisite: course 161. Electrical Engineering 1 (or Physics 1C). Utilization of ceramics in microelectronics; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferroelectric ceramics and electrical- and optical devices; optical wave guide applications and designs.

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 for wide range of audiences. Learning environment is highly supportive and interactive. It helps students creatively develop and greatly expand effectiveness of their communication and presentation skills. 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 several crucial steps, including brainstorming, choosing title, coming up with outline, concise writing of first draft, peer-reading, and final submission. Other subjects include writing style, word choices, and grammar. Letter grading.

Mr. Xie

CM180. Introduction to Biomatials. (4) (Same as Biomedical Engineering CM180.) Lecture, three hours; discussion, one hour; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course 104. 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 who are part of research group. Discussion of research methods, technical 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. Culuminating paper or project required. Occasional 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.

(F,W,Sp)

Graduate Courses


Mr. Y. Yang (F)


Mr. Tu (Sp)

210. Diffraction Methods in Science of Materials. (4) (Formerly numbered 245C.) Lecture, four hours; discussion, one hour; outside study, eight hours. 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 salts; biodegradation; chemical and mechanical weathering; earthquakes, frost, flooding, and wind; sandblasting; structural failure, cleaning, and desalination; sheltering and limited accessibility; fixing, consolidation, and protective surface treatments. Letter grading.

M215. Techniques and Materials of Archaeological and Cultural Materials: In-Situ and Ex-Situ Architectural Decorative Surfaces. (4) (Same as Art History M203F and Conservation M250.) Seminar, two hours; laboratory, three hours; requisites: course M216 or C112 or Conservation C110. Recommended prerequisite: Conservation C215. Designed for graduate conservation and art history students. Principles of archaeological conservation of in-situ and ex-situ monumental architectural and cultural materials, with focus on rock art, wall paintings, polychrome sculpture, decorative architectural elements, and mosaics, through study of their constituent material and technological development, and the application of文物保护 practices and theoretical approaches for the protection of archaeological and cultural sites; study of traditional and scientific knowledge and techniques of conservation materials and systems used in the protection and conservation of archaeological and cultural materials.

M216. Science of Conservation Materials and Methods I. (4) (Same as Conservation M216.) Seminar, one hour; laboratory, three hours. Recommended prerequisite: course 104. Introduction to physical, chemical, and mechanical properties of conservation materials (employed for preservation of archaeological and cultural materials) and their aging characteristics. Science and approaches to traditional and organic and inorganic systems and introduction of novel technology based on biomimelization processes and nanostructured materials. Letter grading.

M221. 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, crystal structure, band theory, optical and transport properties, novel materials systems, and characterization. Letter grading.

Mr. Noskys (Sp)

222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 112. Thermodynamics and kinetics that affect semiconductor growth and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), heteroepi-
223. Materials Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131, Fabricating thin films, and other strengthening properties 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, processing, and properties. Letter grading. Mr. Dunn (Sp, even years)

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


226. Si-CMOS Technology: Selected Topics in Materials Science. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Recommended preparation: Electrical Engineering 221B. Requisites: courses 130, 131, 200, 221, 222. Selected topics in materials science from modern Si-CMOS technology, including technological challenges in high k/metal gate stacks, strained Si FETs, SOI and three-dimensional FETs, source/drain engineering, and transient-enhanced diffusion, nonvolatile memory, and spin-based electronics. Letter grading. Mr. Pei (W)


252. Organic Polymer Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on materials chemistry and basic properties of polymer blends and polymers; heavily doped, highly conducting polymers; applications as processable metals in and various electronics, optical, and electrochromic devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

270. Computer Simulations of Materials. (4) Lecture, four hours; outside study, eight hours. Introduction 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 basic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of existing computer programs and development of new algorithms. Computer experiments can be used to study interesting phenomena in materials science. Hands-on computer experiments. Letter grading. Mr. Ozolins (F)

271. Electronic Structure of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: basic knowledge of quantum mechanics. Recommended requisite: course 200. Introduction to modern first-principles electronic structure calculations for various types of modern materials. Properties of electrons and interatomic bonding in molecules, crystals, and liquids, with emphasis on practical methods for solving Schrödinger equation and using it to calculate physical properties such as elastic constants, equilibrium structures, binding energies, vibrational frequencies, electronic band gaps and band structures, properties of defects, surfaces, interfaces, and materials in extreme environments. Experience with modern density-functional theory code. Letter grading. Mr. Ozolins (W)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Strongly recommended requisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding basic principles that distinguish nanoscale materials (characterize below 100 nm) from more common microstructured materials. Explanation of new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics include structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assembly on surfaces and in liquid solutions, mechanical properties of nanostructured materials, molecular electronics, spin-based electronics, and proposed realizations of quantum computing. Discussion of current and future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. Ozolins (F)

CM280. Introduction to Biomaterials. (4) (Same as Biomedical Engineering CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: courses 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair or repair 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 to 12) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Seminar 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)

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.

597B. Preparation for Ph.D. Preliminary 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.

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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Judy I. Shane, M.S.
Mahmoud Youssif, Ph.D.

Adjunct Professors
Leslie M. Lackman, Ph.D.
Wilbur J. Marner, Ph.D.
Neil B. Morley, Ph.D.
Robert S. Shafer, Ph.D.
Ronaldo Szilard, 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 nationís 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
In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: (1) to teach students how to apply their rigorous undergraduate education to creatively solve technical problems facing society and (2) to prepare them for successful and productive careers or graduate studies in mechanical or aerospace or other engineering fields and/or further studies in other fields such as medicine, business, and law.

Undergraduate Study
The Aerospace Engineering and Mechanical Engineering majors are designated capstone majors. 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 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 ABET-accredited 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;
The Major
Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, 150P, 154S, 155 or 161A or 169A, 157A, 157S, 166A, 171A, 182A; two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104) if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper division course or courses from the department except for Mechanical and Aerospace Engineering 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 162B, 162M); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131A (unless taken as a required course), 131AL, C132A, 133A, 133AL, 150C, C150G, 150R, 153A, 155, 157A, 161A, 161B, 162C, 163A, 166C, M168, 169A, 171B, 172, 174, C175A, CM180, CM180L, 181A, 182B, 182C, 184, 185, C186, C187L. For information on University and general education requirements, see Requirements for B.S. Degrees on page 19 or http://www.registrar.ucla.edu/ge/.

Graduate Study
For information on graduate admission, see Graduate Programs, page 23. The following introductory information is based on the 2010-11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www.gdnet.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 student's 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 adviser's 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 are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor's degree may not be applied toward a graduate degree at UCLA. The courses should be selected so that the breadth requirements and the requirements at the graduate level are met. The breadth requirements are only applicable to students who do not have a B.S. degree from an ABET-accredited aerospace or mechanical engineering program.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering
Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or 150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 250C, 250D, 250F, 253B, 254A, 255B, 256F, 263B, 269D, or 271B. The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.
Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162B 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, 256A, 256B, 269A, 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 graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Manufacturing Engineering M.S.

Areas of Study

Consult the department.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. Choices may be made from the following major areas:

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 163A, M168, 174, 183, 184, 185.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, CM280A, 293, 294, 295A, 295B, 296A, 296B, 297.

Additional Courses. The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design M226B, M227B, 227D; Computer Science 241A, 241B; Management 240A, 240D, 241A, 241B, 242A, 242B, 243B, 243C; Mathematics 120A, 120B.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic 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 graduate courses. Contact the department Student Affairs Office for more information.

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 students 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 Mechanical and Aerospace Engineering Department at UCLA. The outside member must be a UCLA faculty member outside the Mechanical and Aerospace Engineering 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, biofluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, bio fluid mechanics, hypersonics, reactive flow, fluid stability, turbulence, and experimental methods.

Heat and Mass Transfer
The heat and mass transfer field includes studies of convection, radiation, conduction, evaporation, condensation, boiling and two-phase flow, chemically reacting and radiating flow, instability and turbulent flow, reactive flows in porous media, as well as transport phenomena in support of microscale and nanoscale thermosciences, energy, bioMEMS/NEMS, and microfabrication/nanofabrication.

Manufacturing and Design
The program is developed around an integrated approach to manufacturing and design. It includes study of manufacturing and design aspects of mechanical systems, material behavior and processing, robotics and manufacturing systems, CAD/CAM theory and applications, computational geometry and geometrical modeling, composite materials and structures, automation and digital control systems, microdevices and nanodevices, radio frequency identification (RFID), and wireless systems.

Nanoelectromechanical/Microelectromechanical Systems

The nanoelectromechanical/microelectromechanical systems (NEMS/MEMS) field focuses on science and engineering issues ranging in size from nanometers to millimeters and includes both experimental and theoretical studies covering fundamentals to applications. The study topics include microscience, top-down and bottom-up nanofabrication/microfabrication technologies, molecular fluidic phenomena, nanoscale/microscale material processing, biomolecular signatures, heat transfer at the nanoscale, and system integration. The program is highly interdisciplinary in nature.

Structural and Solid Mechanics

The solid mechanics program features theoretical, numerical, and experimental studies, including fracture mechanics and damage tolerance, micromechanics with emphasis on technical applications, wave propagation and nondestructive evaluation, mechanics of composite materials, mechanics of thin films and interfaces, analysis of coupled electro-magneto-thermomechanical material systems, and ferroelectric materials. The structural mechanics program includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aeroelasticity, fluid structure interaction, computational transonic aeroelasticity, biomechanics with applications ranging from whole organs to molecular and cellular structures, structural optimization, finite element methods and related computational techniques, structural mechanics of composite material components, structural
health monitoring, and analysis of adaptive structures.

**Systems and Control**
The program features systems engineering principles and applied mathematical methods of modeling, analysis, and design of continuous- and discrete-time control systems. Emphasis is on modern applications in engineering, systems concepts, feedback and control principles, stability concepts, applied optimal control, differential games, computational methods, simulation, and computer process control. Systems and control research and education in the department cover a broad spectrum of topics primarily based in aerospace and mechanical engineering applications. However, the Chemical and Biomolecular Engineering and Electrical Engineering Departments also have active programs in control systems, and collaboration across departments among faculty members and students in both teaching and research is common.

**Ad Hoc Major Fields**
The ad hoc major fields program has sufficient flexibility that students can form academic major fields in their area of interest if the proposals are supported by several faculty members. Previous fields of study included acoustics, system risk and reliability, and engineering thermodynamics. Nuclear science and engineering, a former active major field, is available on an ad hoc basis only.

**Facilities**
The Mechanical and Aerospace Engineering Department has a number of experimental facilities at which both fundamental and applied research is being conducted. More information is at http://www.mae.ucla.edu.

**Active Materials Laboratory**
The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, magnetostrictive, shape memory alloys, and fiber optic sensors. The laboratory has manufacturing facilities to fabricate magnetostrictive composites and thin film shape memory alloys. Testing active material systems is performed on one of four servo-hydraulic load frames. All of the load frames are equipped with thermal chambers, solenoids, and electrical power supplies.

**Autonomous Vehicle Systems Instrumentation Laboratory**
The Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. The AVSIL contains a hardware-in-the-loop (HIL) simulator designed and built at UCLA that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the Inter-state 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 Beowulf linux clusters for numerical simulation of transitional, turbulent, and high speed compressible flows, with and without reaction, as well as the sound that they produce. The laboratory has access to supercomputers (large clusters of parallel processors on various platforms) at NSF PACI Centers and DoD High-Performance Computing Centers.

**Energy and Propulsion Research Laboratory**
The Energy and Propulsion Research Laboratory is engaged in research and education pertaining to the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research is directed toward the development of fundamental engineering knowledge as well as tools for solving critical national problems, with current applications to improved engine efficiency, reduced emissions, alternative fuels, and advanced high-speed air breathing and rocket propulsion systems.

**Fluid Mechanics Research Laboratory**
The Fluid Mechanics Research Laboratory includes a full line of water tunnels equipped with various advanced transducers (MEMS-based sensors and actuators, particle image anemometer, laser Doppler anemometer, hot-wire anemometers) and data acquisition systems.

**Fusion Science and Technology Center**
The Fusion Science and Technology Center includes a number of state-of-the-art experimental facilities for conducting research in fusion engineering. The center includes experimental facilities for (1) liquid metal magnetohydrodynamic fluid flow dynamics and heat transfer, (2) thick and thin liquid metal systems exposed to intense particle and heat flux loads, and (3) metallic and ceramic material thermo-mechanics.
Heat Transfer Laboratories
The Heat Transfer Laboratories are used for experimental research on heat transfer and thermal hydraulics. The laboratories are equipped with several flow loops, high-current power supplies, high-frequency induction power supplies, holography and hot-wire anemometry setups, and state-of-the-art data acquisition systems.

Materials Degradation Characterization Laboratory
The Materials Degradation Characterization Laboratory is used for the characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and for research on fracture mechanics and ultrasonic nondestructive evaluation.

Micro and Nano Manufacturing Laboratory
The Micro and Nano Manufacturing Laboratory is equipped with a fume hood, wafer saw, wire bonder, electroplating setup including vacuum capability, various microscopes including fluorescent and 3D scooping, various probe stations including RF capability, vibration-isolation and optical tables, environmental chambers, drop dispensing systems, 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/DAC systems, and a quad-core workstation with 32GB RAM.

Plasma and Beam Assisted Manufacturing Laboratory
The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for the purpose of processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power D.C. supplies (400kw), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

Plasma Propulsion Laboratory
The Plasma Propulsion Laboratory includes vacuum systems, power supplies, and diagnostics for the study of plasma propulsion devices.

Subsonic Wind Tunnel
The 3 x 3-foot Subsonic Wind Tunnel is used for research on unsteady aerodynamics on oscillating airfoils and instruction.

Thin Films, Interfaces, Composites, Characterization Laboratory
The Thin Films, Interfaces, Composites, Characterization Laboratory consists of a Nd:YAG laser of 1 Joule capacity with three ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 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 multiaxial stress state.

Faculty Areas of Thesis Guidance
Professors
Mohamed A. Abdou, Ph.D. (Wisconsin, 1973) Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermomechanics, thermal hydraulics, fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-material interactions; blankets and high heat flux components; experiments, modeling and analysis
Oddvar O. Bendiksen, Ph.D. (UCLA, 1980) Classical and computational aerelasticity, structural dynamics and unsteady aerodynamics
Gregory P. Carman, Ph.D. (Virginia Tech, 1991) Electromagnetoeelasticity models, fatigue characterization of piezoelectric ceramics, magnetostrictive composites, characterizing shape memory alloys, fiber-optic sensors, and design of damage detection systems, micro-mechanical analysis of composite materials, experimentally evaluating damage in components
Ivan Catton, Ph.D. (UCLA, 1966) Heat transfer and fluid mechanics, transport phenomena in porous media, nucleonics heat transfer and thermal hydraulics, natural and forced convection, thermal/hydrodynamic stability, turbulence
Jiun-Shyan (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. (UC Berkeley, 1996) Nanoscale science and engineering, micro-and nano-fabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems
Vijay K. Dhir, Ph.D. (Kentucky, 1972) Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling
Rajit Gadh, Ph.D. (Carnegie Mellon, 1991) Mobile Internet, web-based product design, wireless and collaborative engineering, CAD/visualization
Nasr M. Ghoniem, Ph.D. (Wisconsin, 1977) Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ion, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy
James S. Gibson, Ph.D. (U. Texas, Austin, 1975) Control and identification of dynamical systems, optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation
Vijay Gupta, Ph.D. (MIT, 1989) Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974) Molecular fluidic phenomena, microelectromechanical systems (MEMS), bionano technologies, biomolecular sensor arrays, control
of cellular complex systems, rapid search of combinatorial medicine
Tetsuya Iwasaki, Ph.D. (Purdue, 1993)
Dynamical systems, robust and optimal con-
trols, nonlinear oscillators, resonance entrain-
ment, modeling and analysis of neuronal control circuits for animal locomotion, central pattern generators, body-fluid interaction dur-
ing undulatory and oscillatory swimming
Ann R. Karagözian, Ph.D. (Caltech, 1982)
Fluid mechanics and combustion with appli-
cations to internal combustion engine efficiency, reduced emissions, alternative fuels, and advanced high-speed air breathing and rocket propulsion systems
Chang-Jin (C-J) Kim, Ph.D. (UC Berkeley, 1991)
Microelectromechanical systems; micro/nano fabrication technologies; structures, actu-
tors, devices, and systems; microfluidics involving surface tension (especially droplets)
J. John Kim, Ph.D. (Stanford, 1978)
Turbulence, numerical simulation of turbulent and transitional flows, application of control theories to flow control
Adrienne Lavine, Ph.D. (UC 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, satellite remote sensing with application to clouds and aerosols in the earth’s atmosphere
Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1978)
Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensor and actuator applications, fracture mechan-
ics and failure analysis
Ajit K. Mal, Ph.D. (Calcutta U., 1964)
Mechanics of solids, fractures and failure, wave propagation, nondestructive evalua-
tion, composite materials
Robert T. McCluskey, Ph.D. (Caltech, 1995)
Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation
Anthony F. Mills, Ph.D. (UC Berkeley, 1965)
Convective heat and mass transfer, conden-
sation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers
Owen I. Smith, Ph.D. (UC Berkeley, 1977)
Combustion and combustion-generated air pollutants, physical and chemical kinetics of combustion systems, semiconduc-
tor chemical vapor deposition
Jason 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. (UC Berkeley, 1988)
Modeling and control of dynamic systems with applications in mechanical systems, manufacturing processes, automotive sys-
tems, and energy systems, digital control, repetitive and learning control, adaptive and optimal control, mechatronics
Daniel C.H. Yang, Ph.D. (Rutgers, 1982)
Robotics and mechanisms; CAD/CAM sys-
tems, computer-controlled machines
Xiaolin Zhong, Ph.D. (Stanford, 1991)
Computational fluid dynamics, hypersonic flow, rarefied gas dynamics, numerical simu-
lation of transient hypersonic flow with none-
quilibrium real gas effects, instability of hypersonic boundary layers

Professors Emeriti
Andrew F. Charwat, Ph.D. (UC Berkeley, 1952)
Experimental fluid mechanics, two-phase flow, ocean thermal energy conversion
Aeroelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating sys-
tems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aeroelastic con-
strains
H. Thomas Hahn, Ph.D. (Pennsylvania State, 1971)
Nanocomposites, multifunctional compos-
tes, nanomechanics, rapid prototyping, informa-
tion systems
Thermal convection, thermocapillary convec-
tion, stability of flow flows, stratified and rotating flows, interfacial phenomena, micro-
gravity fluid dynamics
Michael A. Melkanoff, Ph.D. (UCLA, 1955)
Programming languages, data structures, database design, relational models, simul-
ation systems, robotics, computer-aided design and manufacturing, numerical-con-
trolled machinery
D. Lewis Mingori, Ph.D. (Stanford, 1966)
Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles
Peter A. Monkowitz, Ph.D. (E.T.H., Federal Insti-
tute of Technology, Zurich, 1977)
Fluid mechanics, internal acoustics and noise produced by turbulent flows
Philip F. O'Brien, M.S. (UCLA, 1949)
Industrial engineering, environmental design, thermal and luminous engineering systems
David Okrent, Ph.D. (Harvard, 1951)
Fast reactors, reactor physics, nuclear reac-
tor safety, nuclear fuel element behavior, risk-
benefit studies, nuclear environmental safety, fusion reactor design
Lucien A. Schmit, Jr., M.S. (MIT, 1950)
Structural mechanics, optimization, auto-
designed design methods for structural systems and components, application of finite element analysis techniques and mathematical pro-
gramming algorithms in structural design, analysis and synthesis methods for fiber com-
posite structural components
Richard Stern, Ph.D. (UCLA, 1964)
Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics
Russell A. Westmann, Ph.D. (UC Berkeley, 1962)
Mechanics of solid bodies, fracture mechan-
ics, adhesive mechanics, composite materi-
als, theoretical soil mechanics, mixed boundary value problems

Associate Professors
Jeff D. Eldredge, Ph.D. (Caltech, 2002)
Numerical simulations of fluid dynamics, bio-
spired locomotion in fluids, transition and turbulence of high-speed flows, aerodynam-
ically generated sound, vortex-based numerical methods, simulations of biomedical flows
Y. Sungtae Ju, Ph.D. (Stanford, 1999)
Heat transfer, thermodynamics, microelectro-
mechanical and nanoelectromechanical sys-
tems (MEMS/NEMS), magnetism, nano-bio technology
H. Pirouz Kavehpour, Ph.D. (MIT, 2003)
Microscale fluid mechanics, transport phe-
omena in biological systems, physics of contact line phenomena, complex fluids, non-
isothermal flows, micro- and nano-heat guides, microtechnology
Computational structural and solid mechan-
ics, finite element methods, continuum biomechanics, nanomechanics of biological systems
Laurent Pilon, Ph.D. (Purdue, 2002)
Interfacial and surface phenomena, radia-
tion transfer, materials synthesis, multi-phase flow, heterogeneous media

Assistant Professors
Pei-Yu Chiou, Ph.D. (UC Berkeley, 2005)
BioMEMS, biophotonics, electrokinetics, optical manipulation, optoelectronic devices
Richard E. Wirtz, Ph.D. (UC Berkeley, 2003)
Space and plasma propulsion, partially ion-
ized plasma discharges, behavior of mini-
ture plasma devices, spacecraft and space mission design, wind energy, solar thermal energy

Lecturers
Ravesh A. Narine, Ph.D. (UCLA, 1974)
Heat transfer and thermal science
C.H. Chang, M.S. (UCLA, 1985), Emeritus
Computer-aided manufacturing and numeri-
cal control
Amiya K. Chatterjee, Ph.D. (UCLA, 1976)
Elastic wave propagation and penetration dynamics
Carl F. Rudolf, Ph.D. (Caltech, 1993)
Robotics, computing, mechanical design, instrument technology, technology manage-
ment
Alexander Samson, Ph.D. (U. New South Wales, 1968), Emeritus
Electromechanical system design, mechan-
i cal design, design of mechanical energy sys-
tems

Adjunct Professors
Leslie M. Lackman, Ph.D. (UC Berkeley, 1967)
Structural analysis and design, composite structures, engineering management
Wilbur J. Marner, Ph.D. (South Carolina, 1969)
Thermal sciences, system design
Neil B. Morley, Ph.D. (UCLA, 1994)
Experimental and computational fluid mechanics
Robert S. Shafer, Ph.D. (UCLA, 1985)
Radiation interaction with materials, micro-
structure evolution modeling, plasma and laser processing, fusion technology research, fusion reactor component design, material property ROMBS databases
Ronaldo Szilard, Ph.D. (UCLA, 1992)
Nuclear engineering, nuclear reload licens-
ing, core design, core monitoring processes, and nuclear methods development

Lower Division Courses
15. Technical Communication for Engineers. (2) Lecture, two hours; outside study, four hours. Requi-
 site: English Composition 3. Understanding writing process. Determining the purpose. Prewriting, Prin-
ciples of organizing technical information. Eliminating unnecessary words, structuring paragraphs clearly, structuring effective sentences. Writing abstracts, in-
troductions, and conclusions. Drafting and revising coherent documents. Writing collaboratively. Letter grading.
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 UC, P.R. grading.
94. Introduction to Computer-Aided Design and Drafting. (4) Lecture, two hours; laboratory, four hours. Fundamentals of computer graphics and two- and three-dimensional modeling on computer-aided design and drafting systems. Students use one or more online computer systems to design and display various objects. Letter grading. Mr. Yang (F,Sp)
99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower-
division students under guidance of faculty mentor. Students must be in good academic standing and en-
rolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.
Upper Division Courses


103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Physics 32B, Mathematics 33A, Physics 33B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading. Mr. Kaveshpour, Mr. J. Kim (F, W, Sp).

105A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Continuum assumption, temperature, and thermodynamic processes. First law and concept of entropy; second law and concept of energy; equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading. Mr. Pilon (F, W, Sp).

105D. Transport Phenomena. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32B, Mathematics 32B, Physics 33B. Transport phenomena; heat conduction, mass species diffusion, convective and heat mass transfer, and reaction. Engineering applications in thermal and environmental control. Letter grading. Mr. Ju (F, Sp).

107. Introduction to Modeling and Analysis of Dynamic Systems. (4) Lecture, three hours; discussion, one hour; outside study, four hours. Requisites: Computer Science 31, Electrical Engineering 100. Introduction to modeling of physical systems, with examples of mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency response, first- and second-order system transient response analysis, and numerical solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response. Block diagram representation and response of interconnections of systems. Hands-on experience using computer simulation packages. Letter grading. Mr. M'Closkey, Mr. Tsao (F, W, Sp).


131AL. Thermodynamics and Heat Transfer Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 131A, and 157 or 157S. Experimental study of physical phenomena and engineering systems using modern data acquisition and processing techniques. Experiments include studies of heat transfer, forced and natural convection, forced convective cooling tower, heat exchanger, and internal combustion engine. Students take and analyze data and discuss physical phenomena. Letter grading. Mr. Mills (Not offered 2010-11).


133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, reactions, evaporative and nonreactive fluid flow systems. Letter grading. Mr. Catton (F, Sp).

133AL. Power Conversion Thermodynamics Laboratory. (4) Laboratory, eight hours; outside study, eight hours. Requisites: courses 133A, and 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 operation of characteristics of actual Brayton cycle, Rankine cycle, compressive refrigeration unit, and absorption refrigeration unit. Letter grading. Mr. Catton (Sp).

134. Design and Operation of Thermal Hydraulic Power Systems. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Requisites: courses 133A, 133AL. Thermal hydraulic design, maintenance and operation of power systems, gas turbines, steam turbines, centrifugal refrigeration units, absorption refrigeration units, compressors, valves and piping systems, and instrumentation and control systems. Letter grading. Mr. Catton (Not offered 2010-11).

135. Fundamentals of Nuclear Science and Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20A, Mathematics 33B. Review of nuclear physics, radioactivity and decay, and radiation interaction with matter. Nuclear fission and fusion processes and mass defect, chain reactions, critically, neutron diffusion, fission products, and methods of analysis. Introduction to nuclear power plants for commercial electricity production, space power, spacecraft propulsion, nuclear fusion, and nuclear science for medical uses. Letter grading. Mr. Morley (Sp).

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 105D. Recommended: courses 131A, 133A. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, solar, and wind power. Letter grading. Mr. Mills (W).

CM140. Introduction to Biomechanics. (4) (Same as Biomedical Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 102, 156A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power genera- tion. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading. Mr. Gupta (W).


150B. Aerodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: 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: shock waves, Prandtl-Meyer expansion. Linearized subsonic and supersonic flow around airfoils and wings. Wave drag. Transonic flow. Letter grading. Mr. Zhong (Sp).

150C. Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 105A. Chemical thermodynamics of ideal gas mixtures, premixed and diffusion flames, explosions and detonations, combustion chemistry, high explo- sive formation, Combustion products, heat transfer and internal combustion engines; heating applications. Letter grading. Ms. Karagözian, Mr. Smith (W).

C150G. Fluid Dynamics of Biological Systems. (4) (Former: courses 133G, 150G) Lecture, eight hours; outside study, eight hours. Requisites: course 103. Mechanics of aquatic locomotion; insect and bird flight aerodynamics; pulsatile flow in circulatory sys- tem; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial diseases. Concur- rently scheduled with course C250G. Letter grading. Mr. Eldredge (Not offered 2010-11).

150P. 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, advanced aircraft engine systems. Letter grading. Ms. Karagözian, Mr. Smith (F).

150R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103, 150A. Not open to students with credit for both courses 161B and 161R. Rocket propulsion concepts, including chemi- cal rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rockets, and solar-powered rockets. Students design and build rockets in launch vehicle technologies. Letter grading. Ms. Karagözian, Mr. Smith (Sp).

153A. Engineering Acoustics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 154A, 154B. Chemical premi- nary design of aircraft, including weight estimation, performance and stability, and control consideration. Term assignment consists of preliminary design of low-speed aircraft. Letter grading. Mr. Bendiksen (W).


154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 152A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed
for design of aircraft. Effects of airplane flexibility on stability derivatives. Letter grading. Mr. Bendiksen (F)

155. Intermediate Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrange equation, variational principles, central force problems; kinematics and dynamics of rigid bodies; Euler equations, motion of rotating bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading. Mr. Gibson (F)

156A. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 182A. Not open to students with credit for course 166A. Concepts of stress, strain, and material behavior. Stresses in loaded beams with symmetric and asymmetric cross sections. Torsion of cylinders and thin-walled structures, shear flow. Stresses in pressure vessels, press-fit and shrink-fit problems, rotating shafts. Curved beams. Contact stresses. Strength and failure, plastic deformation, fatigue, elastic instability. Letter grading. Mr. Mai (F,W)

157. Basic Mechanical Engineering Laboratory. (4) Laboratory, four hours; outside study, eight hours. Requisites: courses 101, 103, 105A, 105D, Electrical Engineering 100. Methods of measurement of basic quantities. Basic mechanics experiment: heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Gholami, Mr. Mills (FW,Sp)

157A. Basic Aerospace/Aeronautical Laboratory. (4) Laboratory, four hours; outside study, four hours. Requisites: courses 150A, 150B, 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 experimental programs and use of modern experimental tools and techniques in field. Letter grading. Mr. Kaviani, Mr. Stouffer (S)

157S. Basic Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. 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 and interpretation of experiments; understanding of basic physical principles and characteristics of structures/systems of relevance to aerospace engineering. Letter grading. Mr. Ju (W,Sp)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102. Recommended: course 182A. Space environment of Earth, trajectories and orbits, space launches and staging, two-body problem, orbital transfer and rendezvous, problem of three bodies, elementary perturbation theory, influence of Earth's oblateness. Letter grading. Mr. Wirz (F)

161B. Introduction to Space Technology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended preparation: courses 102, 150P, 161A. Not open to students with credit for both courses 150R and 161R. Propulsion requirements for typical space missions, thermodynamics of propulsion, internal ballistics, regenerative cooling, liquid propellant feed systems, POGO instability. Electric propulsion. Multistage rockets, separation dynamics. Satellite orbits, materials, loads and vibrations. Thermal control of spacecraft. Letter grading. Mr. Wirz (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161B or 161R. Coverage of preliminary design, by students, of small spacecraft carrying lightweight scientific payload with modest requirements for electric power, lifetime, and attitude stability. Students work in groups of four, each student responsible primarily for one subsystem and for integration with whole. Letter grading. Mr. Wirz (Sp)

161D. Space Technology Hardware Design. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Recommended requisite or corequisite: course 161B. Design, by students, of hardware with applications to space technology. Designs are then built by HSSEAS professional machine shop and tested by students. New project carried out each year. Mr. Wirz (Not offered 2010-11)

161R. Space Technology and Rocket Propulsion. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102, or courses 103, 105A. Recommended: courses 105D, 161A. Not open for credit to students with credit for both courses 150R and 161B. Launch vehicles and rocket propulsion, including rocket engines (race, chemical and solid propellants), hybrid rocket engines, electric (plasma) propulsion using solar and nuclear power. Propulsion requirements for typical space missions and multistage rockets. Spacecraft systems and dynamics, including power, instruments, communications, structure, materials, thermal control, and attitude control. Letter grading. Ms. Karagoniz, Mr. Wirz (Not offered 2010-11)


162B. Mechanical Product Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 94, 156A, 162A, 183. Electrical Engineering 110L. Lecture and laboratory (design) course involving modern design theory and methodology for development of mechanical products. Economics, marketing, quality, and product-entailability. Design considerations taught and applied to hands-on design project. Letter grading. Mr. Yang (F,Sp)

162C. Electromechanical System Design Labora - tory. (4) Lecture, one hour; laboratory, eight hours; outside study, three hours. Requisite: course 162B. Laboratory and design course consisting of design, development, construction, and testing of complex mechanical and electromechanical systems. Assembled machine is instrumented and monitored for operational characteristics. Letter grading. Mr. Tsao (Not offered 2010-11)

162D. Mechanical Engineering Design I. (4) Lecture, two hours; laboratory, eight 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 design management, design of thermal systems, mecha- tronics, mechanical systems, and mechanical component. 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. Gholami, Mr. Tsao, Mr. Yang (W)

162E. Mechanical Engineering Design II. (4) Lecture/discussion, four hours; outside study, eight hours. Enforced requisite: course 162D. Limited to seniors. Second of two mechanical engineering capstone design courses. Conceptual design and continue design projects started in course 162D, making use of CAD design laboratory, CAD analysis laboratory, and mechatronics laboratory. Design theory, design tools, economic analysis, manufacturing and material quality, intellectual property, design for manufacture and assembly, design for safety and reliability, and engineering ethics. Students conduct hands-on design, fabri- cation, and manufacturing project demonstrations or competition. Preparation of design project presentations in both oral and written formats. Letter grading. Mr. Gholami, Mr. Tsao, Mr. Yang (Sp)

162M. Senior Engineering Design. (4) Lecture, one hour; laboratory, six hours; outside study, six hours. Requisites: courses 101, 162A, 162B, 171A. Must be taken in last two academic terms of students' programs. Analytical course of large engineering system. Design factors include functionality, efficiency, economy, safety, reliability, aesthetics, and societal and environmental considerations. Emphasis on engineering specifications and drawings to be presented by design teams. Letter grading. Mr. Yang (W)

163A. Introduction to Computer-Controlled Ma - chines. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite or corequisite: course 171A. Modeling of computer-controlled machines, including electrical and electronic elements, microcontroller elements, and overall control, electromechanical systems. Motion and command generation, servo-controller design, and computer/machine interfacing. Letter grading. Mr. Tsao (Not offered 2010-11)

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-strain laws, yield and fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled cross sections; shear flow, shear-lag; combined bending torsion of thin-walled, stiffened structures; flight dynamics for aerospace vehicles; elements of plate theory; buckling of columns. Letter grading. Mr. Carman (F)

166C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 156A or 166A or Civil Engineering 130. Introduction to the design 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) Formerly numbered 168.) (Same as Civil Engineering M135C.) Lecture, four 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) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; 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. Klug (F,Sp)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101, 102, 107. Fundamentals of vibration theory and applications. Free, forced, and transient vibration of one and two degrees of freedom systems, including damping. Normal modes, coupling, and normal coordinates. Vibration isolation devices, vibrations of continuous systems. Letter grading. Mr. Bendiksen (F)

171A. Introduction to Feedback and Control Sys - tems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 107, 182A. Introduction to feedback principles, control systems design, computer-aided design and system stability, physical system design, design methods, and control systems. Concepts of feedback in engineering and other fields; transform methods; controller design using Nyquist, Bode, and root locus methods; compensation; computer-aided analysis and design. Letter grading. Mr. M'Closkey (FW,Sp)

171B. Digital Control of Physical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 171A or Electrical Engineering 141. Analysis and design of digital control systems. Sampling theory. Z-transformation. Discrete-time system representation. Design using classical methods: performance specifications, root lo -
172. Control System Design Laboratory. (4) Laboratory, eight hours: outside study, four hours. Requisite: course 171A. Application of frequency domain design techniques for control of mechanical systems. Successful student design projects simulate performance measures for control problem, experimentally identify mechanical systems, and develop uncertainty descriptions for design models. Experiments focus on model uncertainty, sensor/actuator placement. Students implement control designs on flexible structures, rate gyroscopes, and inverted pendulum. Detailed reports required. Letter grading. Mr. M. Tsao (Not offered 2010-11)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Mathematics 33A. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control methods by attributes, acceptance sampling. Letter grading. Ms. Lavine (W)

C175A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 107, 182B. Probability spaces, random variables, stochastic processes and sequences, expectation, conditional expectation, Gauss/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C271A. Letter grading. Mr. Speyer (F)

CM180. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Biomedical Engineering CM150 and Electrical Engineering CM150.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4A, 4B, 4L, Corequisite: course CM180L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS devices, microstructures, microsensors, and microactuators. Students design microlamination processes capable of achieving desired MEMS device. Concurrently scheduled with course C271A. Letter grading. Mr. C-J. Kim (F)

CM180L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Biomedical Engineering CM150L and Electrical Engineering CM150L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4A, 4B, 4L. Corequisite: course CM180L. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design fabrication processes and experimentally identify mechanical systems. Letter grading. Mr. C-J. Kim (F)

181A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 182A. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transform; properties of inverse transforms; Fourier transform; properties; convolution, FFT; applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. Ghoenim (W)


184. Introduction to Geometry Modeling. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: course 94, Computer Science 31, 35. Surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transforms, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and implementation. Letter grading. Mr. Gadh (Not offered 2010-11)

185. Introduction to Radio Frequency Identification and its Application in Manufacturing and Supply Chain. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 126B, Computer Science 31, Manufacturing topics cover assembly and systems into assembled products, shipping of such products, and eventually use, maintenance, and recycling of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and assembled products allow them to be tracked automatically as they move and transform through manufacturing supply chain. RFID tags have memory and small CPU that allows information about product status to be written, stored, and transmitted wirelessly. Tag data can then be forwarded by reader to enterprises via software or by RFID middleware. Laser pointers for manufacturing, with focus on automotive and aerospace. Letter grading. Mr. Gadh (Not offered 2010-11)

186. Applied Optics. (Formerly numbered 231C.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Physics 1C, 2C. Fundamental principles of optical systems. Geometric optics and aberration theory. Diffraction and interference, Young’s slit experiment and fringe visibility, Michelson interferometer, multiple-beam interference and thin film coatings. Diffraction theory, Fraunhofer and Fresnel diffraction, Fresnel zone plate. Fiber optics, waveguides and modes, fiber coupling, types of fiber: single and multimode. Concurrently scheduled with course C286. Letter grading. Mr. C-J. Kim (W)

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 biological principles related to these techniques, top-down and bottom-up (self-assembly) nanofabrication, microrheology, and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C287L. Letter grading. Mr. Y. Chen (F)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Special topics in mechanical and aerospace engineering for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated once for credit with topic or instructor change. P/NP or letter grading.

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated once for credit. P/NP or letter grading.

199. Directed Research in Mechanical and Aerospace Engineering. (2 to 4) 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 offered for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F, W, Sp)

Graduate Courses


231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: course 105D. Radiative properties of materials and radiative energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation transfer in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading. Mr. Pilon (F)


231G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisites: course 105D. Heat carriers (photons, electrons, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann trans-

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101, 102, 156A. Underlying physics and mathematics of nuclear reactor (fission) core design. Diffusion theory, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transport theory. Letter grading. Mr. Abdou (Sp)


239B. Seminar: Current Topics in Transport Phenomena. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, student presentations, and projects in areas of current interest in transport phenomena. Letter grading. S/U grading. Letter grading. Mr. Abdou (X)

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 study in current areas of interest in transport phenomena, such as fluid mechanics and heat transfer, turbulence, fluidization, and incineration. Letter grading. S/U grading. Mr. Abdou (alternate years)

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 current areas of interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.

239H. Special Topics in Fusion Physics, Engineering, 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 study in current areas of interest in fusion science and engineering, such as instabilities in burning plasmas, alternate fusion confinement concepts, inertial confinement fusion, fission-fusion hybrid systems, and fusion reactor safety. May be repeated for credit with topic change. S/U grading.

CM240. Introduction to Biomechanics. (4) (Same as Biomedical Engineering CM240.) Lecture, four hours; outside study, six hours. Requisites: courses 101, 102, 156A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function; design of dynamic systems; applications. Heat and mass transfer. Power generation. Laboratory studies and tests. Concurrently scheduled with course CM140. Letter grading.

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Corequisite: course 182B. Development and application of fundamental principles of fluid mechanics at graduate level, with emphasis on incompressible flow. Flow kinematics, basic equations, constitutive relations, exact solutions on the Navier/Stokes equations, vorticity dynamics, decomposition of flow fields, potential flow. Letter grading.

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Fundamental principles of fluid dynamics applied to study of fluid resistance. State of fluid motion discussed in order of advancing Reynolds number; wakes, boundary layers, instability, transition, and turbulent shear flows. Letter grading.

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 150C. Effects of compressibility in viscous and inviscid flows. Steady and unsteady supersonic and hypersonic flows; method of characteristics; small disturbance theories (linearized and hypersonic); shock dynamics. Letter grading.


250E. Spectral Methods in Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 182A, 182B, 182C, 250A, 250B. Introduction to basic concepts and techniques of various spectral methods applied to solving partial differential equations. Topics include spectral representation of functions, discrete Fourier transform, etc. Letter grading.

250F. Hypersonic and Nonequilibrium Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250C. Molecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermal-dynamics for calculation gas properties, equilibriums of real flows, vibrational and chemical rate processes, nonequilibrium flows of real gases, and computational fluid-dynamics methods for nonequilibrium flows. Letter grading.

250G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 103. Mechanics of aquatic locomotion; insect and bird flight aerodynamics; pulsatile flow in circulation system; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial disease. Concurrently scheduled with course C150G. Letter grading.

250H. Advanced Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 169A. Variational principles and Lagrange equations. Kinematics and dynamics of rigid bodies; processions and nutation of spinning bodies. Letter grading.

252B. Turbulence. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B. Characteristics of turbulent flows, conservation and transport equations, statistical description of turbulent flows, scales of turbulent motion, simple turbulent flows, free-shear flows, wall-bounded flows, turbulent modeling, numerical simulations of turbulent flows, and turbulence control. Letter grading.


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 averaging, semiempirical and ab initio potential surfaces, trajectory calculations, reaction rate theories. Practical examples of large-scale chain mechanisms from combustion chemistry of several elements, etc. Letter grading.

253A. Advanced Engineering Acoustics. (4) Lecture, four hours; outside study, eight hours. Advanced studies in engineering acoustics, including three-dimensional wave propagation; propagation in bounded media; Ray acoustics; attenuation mechanisms in fluids. Letter grading. Mr. Eldredge (Spring)

253B. Fundamentals of Aeracoustics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Detailed discussion of plane waves, point sources. Nonlinear, layered and moving media, multiple reflections. Inhomogeneous wave equation. Monopole, dipole, quadrupole source fields from scattering inhomogeneities and turbulence; Lighthill theory; moving sources. Selected applications. Letter grading. Mr. Eldredge (Fall, Winter, Spring)

254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 182A, 182B, 182C. Special topics of current interest in advanced aerodynamics. Examples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamics. Letter grading. Mr. Zhong (Fall, Winter, Spring)

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 169A. Variational principles and Lagrange equations. Kinematics and dynamics of rigid bodies; processions and nutation of spinning bodies. Letter grading.

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A. Concepts of stability; state-space interpretation; stability determination by simulation, linearization, and Lyapunov direct method; the Hamiltonian as a Lyapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear systems. Selected applications. Letter grading. Mr. Gibson (Sp)

256A. Linear Elasticity. (4) (Same as Civil Engineering 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; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions,
cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equations, elasticity, hyperelasticity, thermoporomechanics; linearization of field equations; solution of selected problems. Letter grading.

Mr. Dong, Mr. Mal (W)


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 modeling methods for crack healing, small crack size effects, fatigue, environment-assisted crack initiation, stress intensity factors; engineering applications in stifferened structures, pressure vessels, plates, and shells. Letter grading.

Mr. Gupta (Sp)

M257A. Elastodynamics. (4) (Same as Earth and Space Science M224A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity. Cauchy equation of motion, constitutive relations, boundary and initial conditions. Sources and waves in unbounded isotropic, anisotropic, and dissipative solids. Half-space problems. Guided waves in layered media. Applications to dynamic fracture, non-destructive evaluation (NDE), and mechanical phenomena 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 materials at scales ranging from atomic through microstructure or translational and up to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics and Monte Carlo) and their applications at nanoscale. Developments and applications of dislocation dynamics and statistical mechanics methods in areas of nanostructures and tribology. Nanomechanics, self-assembled nanostructures, and failure phenomena. Presentation of technical applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanostructures, thin films (e.g., optical thermal barrier coatings and ultrathin nanolayer materials), nano-identifiers (e.g., atomic force microscope) and microidentifiers (e.g., atomic force microscope) and microidentifiers (e.g., atomic force microscope) and microidentifiers (e.g., atomic force microscope). Letter grading.

Mr. Ghiomi (W, alternate years)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assignments in research problems leading to term paper or oral presentation (possible help from guest instructors). Letter grading.

Mr. Smith

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid mechanics on topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability. 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, discussions, and student presentations and projects in areas of current interest in mechanical engineering. May repeat for credit.


Mr. Klug (F)


Mr. Klug

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 166C. Constitutive relations for fluid-like and solid-like materials. Fiber-optic sensor technology. Micro/macrowave, including classical lamination theory, shear lag theory; concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials design. Size effect, scale dependence and shape and dimorphism. Letter grading.

Mr. Carman (Sp)

263A. Analytical Foundations of Motion Controllers (Lecture, four hours; outside study, eight hours. Recommended requisite: courses 163A, 234A). Theory of motion control for modern computer-controlled machines; multi-axis computer-controlled machines; machine kinematics and dynamics; multi-axis motion coordination; coordination with desired speed and acceleration; jerk analysis; motion command generation; theory and design of controller interpolators; motion trajectory design and analysis; speed-interpolating time relationship. Letter grading.

Mr. Yang

263B. Spacecraft Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Recommended: course 255B. Modeling, dynamics and control of spacecraft and space station. Motion description; spin and dual-spin spacecraft dynamics; spinup through resonance, spinning rocket dynamics; environmental torques in space, modeling and model reduction of flexure, hysteresis, nonlinearities. Letter grading.

Mr. Wirz


Mr. Yang (W)

263D. Advanced Robotics. (4) Lecture, four hours; outside study, eight hours. Recommended preparation: courses 155, 171A, 263C. Motion planning and control of articulated dynamic systems: nonlinear joint control, experiments in joint control and multi-axis coordination, multi-body dynamics, trajectory planning, motion optimization, dynamic performance and manipulator design, kinematic redundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading.

Mr. Hahn


Mr. Bendiksen (W)


Mr. Bendiksen (Sp, alternate years)

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aeroelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow induced instability and response of structural systems. Letter grading.

Mr. Bendiksen (F, alternate years)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engineering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, Fourier transform, Laplace transform, and z-transform. Systems with deterministic inputs and outputs. Connections with transfer function techniques. Letter grading.

Mr. Gibson (F)


Mr. Speyer (F)

C271A. Probability and Stochastic Processes in Dynamical Systems. (4) (Formerly numbered 271A.) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 107, 182A. Probability spaces, random variables, stochastic processes, properties of random variables, processes, expectation, conditional expectation, Gauss/Markov sequences, and minimum variance estimator (Kalmam filter) with applications. Concurrently scheduled with course G175A. Letter grading.

Mr. Speyer (F)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Requisite: course C271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading.

Mr. Speyer (W)


Mr. Speyer

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Requisite: current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading.

Mr. Speyer (W)
M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical Engineering M242A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M280A or Electrical Engineering M240A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on state-space theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorems. Letter grading. Mr. M'Closkey

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Multivariable system performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M'Closkey

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. 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 conversion to continuous-time models. Models identified include transfer functions and state-space models. Examples include identification of simple systems. Letter grading. Mr. Gibson (Sp)

M276. Dynamic Programming. (4) (Same as Electrical Engineering M237.) Lecture, four hours; outside study, eight hours. Recommended requisite: Electrical Engineering 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 models. Introduction to deterministic optimal control. Performance, steady-state optimality, and the maximum principle. Topics include properties, formulation, solution, and the application of optimal control to selected mechanical systems. Letter grading. Mr. Yang (F)

279. Dynamics and Control of Biological Oscillations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171B, M270A. Digital signal processing and control analysis of mechatronic systems. System invariance-based control design and analysis. Lecture, four hours; outside study, six hours. Requisites: courses 171B, M270A. Analysis and design of dynamical mechanisms underlying biocompatible control systems that generate coordinated oscillations. Topics include neuronal information processing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, optical gait (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Iwaski (Sp)

CM280A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Biological Engineering CM250A and Electrical Engineering CM250L.) Lecture, four hours; discussion, one hour; outside study, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course CM180 or CM280A. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, etching, and bonding processes used to construct MEMS. Coverage of corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C.-J. Kim (W)

CM280L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Biomedical Engineering CM250L and Electrical Engineering CM250L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4A, 4BL. Corequisite: course CM280A. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading. Mr. Ho, Mr. C.-J. Kim (F)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Biomedical Engineering M252 and Electrical Engineering M252.) Lecture, four hours; outside study, eight hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, interfacial forces, microfabrication, and test systems. Coverage of mechanical properties, mechanical behavior (e.g., strength/fatigue) as they relate to microscale. Considerable emphasis on emerging experimental approaches to assess design-relevant mechanical properties. Letter grading.

283. Experimental Mechanics for Microelectromechanical Systems (MEMS). (4) Lecture, four hours; outside study, eight hours. Methods, techniques, and philosophies being used to characterize microelectromechanical systems. Machine design, testing, and applications. Material characterization, mechanical/material properties, mechanical characterization. Topics include fundamentals of crystallography, anisotropic material properties (e.g., strength/fatigue) as they relate to microscale. Considerable emphasis on emerging experimental approaches to assess design-relevant mechanical properties. Letter grading.

Mr. Carman (Sp, alternate years)

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. 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. Hsu (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 concepts of interfacial phenomena, including surface tension, surfactants, interfacial thermodynamics, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, microelectromechanical systems, and biological systems. Letter grading.

Mr. Pilon (Sp, alternate years)


Mr. Chiou (Not offered 2010-11)

M287. Nanoscience and Technology. (4) (Same as Electrical Engineering M257) Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanotechnology, nanomaterials, nanoelectronics, and nano-biotechnology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind them and inspire students to create new ideas in multidisciplinary nano areas. Letter grading. Mr. Y. Chen (W)

C287L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Multidisciplinary course that introduces laboratory techniques for nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles of advanced microfabrication techniques, top-down and bottom-up (self-assembly) nanofabrication, nanochip characterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C187L. Letter grading. Mr. Y. Chen (F)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 104, Physics 17. Science and engineering of laser microfabrication of advanced materials, including semiconductors, metals, and insulators. Topics include the effects of top-down methods and advanced materials on laser microstructures, surface modifications (physical/chemical), microstructures for three-dimensional MEMS (micromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter grading.


294. Computational Geometry for Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 174. Computational geometry for design and manufacturing, with special emphasis on curve and surface theory, geometric modeling of curves and surfaces, B-splines and NURBS, computer-aided surface design, computing methods for surface design and manufacture, and current research topics in computational geometry for CAD/CAM systems. Letter grading. Mr. Yang (F)

295B. Internet-Based Collaborative Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course 183. 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 collaboration and software tools to support it. Letter grading.

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


Mr. Ghoniem (Sp, alternate years)

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 transitions, transport 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, Ms. Lavine (Sp, alternate years)


Mr. Hahn

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

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

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

Ms. Lavine (F, W, 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. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

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

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

Master of Science in Engineering Online Program

UCLA
7440 Boelter Hall
Box 951594
Los Angeles, CA 90095-1594
(310) 825-6542
fax: (310) 825-3081
http://msengrol.seas.ucla.edu

Christopher S. Lynch, Ph.D., Director

Scope and Objectives

The primary purpose of the Master of Science in Engineering online degree program is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed. The training and education that the program offers are of significant importance and usefulness to engineers, their employers, California, and the nation. It is at the M.S. level that engineers have the opportunity to learn a specialization in depth, and those engineers with advanced degrees may also renew and update their knowledge of the technology advances that continue to occur at an accelerating rate.

The M.S. program is addressed to those highly qualified employed engineers who, for various reasons, do not attend the on-campus M.S. programs and who are keenly interested in developing up-to-date knowledge of cutting-edge engineering and technology.

Graduate Study

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

The following introductory information is based on the 2010–11 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://www .gdnnet.ucla.edu/gasaa/library/pgmreq intro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.
M.S. in Engineering Online Program

Course Requirements

The program consists of nine courses that make up a program of study. At least five courses must be at the 200 level, and one must be a directed study course. The latter course satisfies the University of California requirement for a capstone event (in the on-campus program the requirement is covered by a comprehensive examination or a thesis); the directed study course consists of an engineering design project that is better suited for the working engineer/computer scientist.

The program is structured in a manner that allows employed engineers/computer scientists to complete the requirements at a part-time pace (e.g., one 100/200-level course per term). Courses are scheduled so that the program can be completed within two academic years plus one additional term.

Advanced Structural Materials

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Director; jyang@seas.ucla.edu

The program provides students with a broad knowledge of advanced structural materials. Courses cover fundamental concepts of science and engineering of lightweight advanced metallic and composite materials, fracture mechanics, damage tolerance and durability, failure analysis and prevention, nondestructive evaluation, structural integrity and life prediction, and design of aerospace structures. Students are required to complete a project on a topic related to structural materials.

Aerospace Engineering

Xiaolin Zhong, Ph.D. (Mechanical and Aerospace Engineering), Director; xiaolin@seas.ucla.edu

The main objective of the program is to provide students with broad knowledge of the major technical areas of aerospace engineering to fulfill the current and future needs of the aerospace industry. Major technical areas include aerodynamics and computational fluid dynamics (CFD), systems and control, and structures and dynamics. Courses cover fundamental concepts of science and engineering of aerodynamics, compressible flow, computational aerodynamics, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, and dynamics of structures. Through a graduate course, students also gain skills in the development and application of CFD codes for solving practical aerospace problems.

If students have taken Mechanical and Aerospace Engineering 150B, 154B, and 171B or the equivalent at their undergraduate institutions, they can take other online-offered courses, approved by the area director, as substitute courses. In addition, students are required to complete a project on a topic related to the three major areas of this program.

Computer Networking

Mario Gerla, Ph.D. (Computer Science), Director; gerla@cs.ucla.edu

Three undergraduate elective courses complement the basic background of the undergraduate electrical engineering or computer science degree with concepts in security, sensors, and wireless communications. The graduate courses expose students to key applications and research areas in the network and distributed systems field. Two required graduate courses cover the Internet and emerging sensor embedded systems. The electives probe different applications domains, including wireless mobile networks, security, network management, distributed P2P systems, and multimedia applications.

Electronic Materials

Ya-Hong Xie, Ph.D. (Materials Science and Engineering), Director; yhx@ucla.edu

The electronic materials program provides students with a knowledge set that is highly relevant to the semiconductor industry. The program has four essential attributes: theoretical background, applied knowledge, exposure to theoretical approaches, and introduction to the emerging field of microelectronics, namely organic electronics. All faculty members have industrial experience and are currently conducting active research in these subject areas.

Integrated Circuits

Dejan Markovic, Ph.D. (Electrical Engineering), Director; dejan@ee.ucla.edu

The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signaling and synchronization, VLSI signal processing, and communication system design. Summer courses are not yet offered in this program; therefore it cannot currently be completed in two calendar years.

Manufacturing and Design

Daniel C.H. Yang, Ph.D. (Mechanical and Aerospace Engineering), Director; dyang@seas.ucla.edu

The manufacturing and design program covers a broad spectrum of fundamental and advanced topics, including mechanical systems, digital control systems, microdevices and nanodevices, wireless systems, failure of materials, composites, and computational geometry. The program prepares students with the higher educational background that is necessary for today's rapidly changing technology needs.

Mechanics of Structures

Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Director; ajit@seas.ucla.edu

The mechanics of structures program provides students with the knowledge required for the analysis and synthesis of modern engineered structures. The fundamental concepts of linear and nonlinear elasticity, plasticity, fracture mechanics, finite element analysis, and mechanics of composites and structural vibrations are developed in a series of undergraduate and graduate courses. These concepts are then applied in solving industry-relevant problems in a number of graduate-level courses. Students develop hands-on experience in using finite element packages for solving realistic structural analysis problems.

Signal Processing and Communications

Kung Yao, Ph.D. (Electrical Engineering), Director; yao@ee.ucla.edu

The program provides training in a set of related topics in signal processing and communications. Students receive advanced training in multimedia systems from the fundamentals of media representation and compression through transmission of signals over communications links and networks.

System Engineering

Peter S. Pao, Ph.D. (Computer Science), Director; peterspao@ucla.edu

System engineering has broad applications that include software, hardware, materials, and electrical and mechanical systems. A set of four core courses is offered that form the foundation of the system engineering program. The sequence of courses is designed for working professionals who are faced with design, development, support, and maintenance of complex systems.

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.
Schoolwide Programs, Courses, and Faculty

UCLA
6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601

(310) 825-2826
http://www.engineer.ucla.edu

Professors Emeriti
Edward P. Coleman, Ph.D.
Allen B. Rosenstein, Ph.D.
Bonham Spence-Campbell, E.E.

Graduate Study

For information on graduate admission to the schoolwide engineering programs and requirements for the Engineer degree and certificate of specialization, see Graduate Programs, page 23.

Faculty Areas of Thesis Guidance

Professors Emeriti
Edward P. Coleman, Ph.D. (Columbia U., 1951)
Design of experimentation; operations management, environment; process of product reliability and quality
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

M10A. Introduction to Complex Systems Science.
(5) (Same as Human Complex Systems M10A.) Lecture, four hours. How macroscopic patterns emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control. Such emergent order, whose explanation cannot be reduced to explanations at level of individual entities, is ubiquitous in biology and human social collectives, but also exists in certain physical processes such as earthquakes and some chemical reactions. Complexity also deals with how such systems undergo sudden changes, including catastrophic breakdowns, in absence of external force or central influence. Key aspect of biological and social collectives is their nature as complex adaptive systems, where individuals and groups adjust their behavior to external conditions. In biological and social systems, complexity science goes beyond traditional mathematics and statistics in its use of multigent computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

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.

67. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team process. Investigation of national need underlying current effort to increase participation of historically underrepresented groups in U.S. technological work force. Letter grading.

95. Internship Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to freshmen/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. Normally, only 4 units of internship are allowed. Individual contract with associate dean required. P/NP grading.

Upper Division Courses

M101. Principles of Nanoscience and Nanotechnology. (4) (Same as Materials Science M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20, and Electrical Engineering 1 or Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron transport, 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. Ozolins (F)
110. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamental principles of micro-level (individual, firm, market) and macro-level (government, international) economics as they relate to technology management. How individuals, firms, and governments impact successful commercialization of high technology products and services. Letter grading. Mr. Hoek (Sp)

111. Introduction to Finance and Marketing for lif product. (4) Lecture, four hours; discussion, six hours. Recommended requisite: course M101. Introduction to po - laboratory to market. Letter grading. UCLA, that are in need of plans for movement from entrepreneurial finance. Students work in small teams to develop ideas into business plans and market them. Course covers cost of capital, and product, return on assets, return on equity, return on invest - value, discounted cash flow, internal rate of return, 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 in - dividual technical essays and one team-written re - search report. Readings address technical issues and writing form. Satisfies engineering writing re - quirement. Letter grading. Mr. Wesel (F,W,Sp)

183EW. Engineering and Society. (Formerly numbered 183.) Lecture, four hours; discussion, three hours; outside study, five hours. Limited to sophomores/junior/senior engineering students. Pro- fessional and ethical considerations in practice of en - gineering. Impact of technology on society and on development of moral and ethical values. Contempo- rary environmental, biological, legal, and social issues created by new technologies. Satisfies technical writing requirement. Letter grading. Mr. Wesel (W)

185EW. Art of Engineering Endeavors. (4) For - merly numbered 185.) Lecture, four hours; discus- - sion, three hours; outside study, five hours. Designed for seniors/junior engineering students. Non - technical skills and experiences necessary for engineering ca - reer success by product development. Emphasis on archi - tecting. Introduction to architecting methodology — principles of architecting through analysis of architecture designs of major existing sys - tems. Discussed for selected elements of architectur - al practice, such as representation models, design progression, and architecture frameworks. Examination of professionalization of system ach - itecture. Letter grading. Mr. Lynch, Mr. Wesel

299. Capstone Project. (4) Activity, 10 hours. Prepa- ration: completion of minimum of four 200-level courses in online M.S. program. Project course that satisfies UCLA M.S. degree comprehensive examination require - ment. Satisfies technical writing requirement. M.S. online degree in Engineering. Project - is completed under individual guidance from UCLA Engineering faculty member and incorporates advanced knowledge learned in M.S. program of study. Letter grading. Mr. Abe, Mr. Cong, Mr. Wesel (W)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associ - ate, 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)

200. Program Management Principles for En- gineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course M101. Designed for graduate students. Practical review of major elements of system engineering process. Course covers key elements: sys- tem mission, constraints, interfaces, time, material, energy, information, and finance; project planning and execution; project control; project risk management; project evaluation; and project management. Satisfies technical writing requirement. Letter grading. Mr. Lynch (W,Sp)

201. Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate stu- dents. Practical review of major elements of system engineering process. Course covers key elements: sys- tem mission, constraints, interfaces, time, material, energy, information, and finance; project planning and execution; project control; project risk management; project evaluation; and project management. Satisfies technical writing requirement. Letter grading. (W)

202. Reliability, Maintainability, and Supportability. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 201. Designed for graduate stu- dents with one to two years work experience. Inte- grated logistic support (ILS) is major driver of system life-cycle cost and one key element of system engi - neering activities. Overview of engineering disci - plines critical to this function — reliability, maintain - ability, and supportability. Letter grading. Mr. Lynch, Mr. Wesel

215. Entrepreneurship for Engineers. (4) Formerly numbered 210.) Designed for graduate students with B.S. degrees in en- gineering or science and one to two years work expe - rience in selected domain. Art and science of archi - tecting. Introduction to architecting methodology — principles of architecting through analysis of architecture designs of major existing sys- tems. Discussed for selected elements of architectur - al practice, such as representation models, design progression, and architecture frameworks. Examination of professionalization of system architecture. Letter grading. Mr. Lynch, Mr. Wesel

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associ - ate, 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)

470A-470D. Engineer in Technical Environment. (3 each) Lecture, three hours. Limited to Engineering Executive Program students. Theory and application of quantitative methods in analysis and synthesis of engineering systems for purpose of making manage - ment decisions. Optimization of outputs with respect to dollar costs, time, material, energy, information, and manpower. Case studies and individual projects. S/U or letter grading. (F,W,Sp)

471A-471B-471C. Engineer in General Environ - ment. (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to En - gineering 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 resistance to change. S/U or letter grading. (In Progress) 471B and S/U or letter grading (471C grading).
472A-472D. Engineer in Business Environment. (3-3-3-1.5) 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, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (472A, 472C) and S/U or letter grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of Large-Scale System. (3-3) Lecture, two and one-half hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495A. Teaching Assistant Training Seminar. (4) (Formerly numbered 495.) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading.

M495B. Supervised Teaching Preparation. (2) (Same as English Composition M495E.) Seminar, two hours. Required of all teaching assistants for Engineering writing courses not exempt by appropriate departmental or program training. Training and mentoring, with focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F, W, S, P)

M495C. Supervised Teaching Preparation. (2) (Same as English Composition M495F.) Seminar, one hour. Required of all teaching assistants in their initial term of teaching Engineering writing courses. Mentoring in group and individual meetings. Continued focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F, W, S, P)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Used to record enrollment of UCLA students in courses taken under cooperative arrangements with USC. S/U grading.
A cell consists of millions of intracellular molecules, which serve as building blocks for its structure and functions. Interactions among these building blocks display the property of self-organization, which serves as the foundation of signaling networks and regulatory pathways. Through these interconnected networks, a cell is the basic unit of life — senses, responds, and adapts to its environment. Three characteristics are commonly observed in all complex systems. The goal of the Center for Cell Control (CCC) at UCLA is to apply an unprecedented approach toward efficiently searching for a potent drug cocktail for guiding biological systems to a directed phenotype. Nanoscale modalities and molecular sensors are used to understand the signal pathway responses under the influence of the drugs. This introduces engineering systems that can be applied toward regulation of a spectrum of cellular functions, such as cancer eradication, viral infection onset control, and stem cell differentiation.

This highly interdisciplinary approach demands strong synergetic collaboration between engineers, biologists, and clinical doctors at UCLA and UC Berkeley. Projects important to the goals of the NIH nanomedicine program are development of a smart petri dish platform with advanced nanoscale modalities, capable of studying signal pathways at the network interaction level; and demonstration of the unique capability to determine optimal multiple drug combinations and apply the resulting drug cocktail as potential therapeutics in pathogenic diseases and cancer.

Three biological systems — stem cell, cancer, and viral infection — have been proposed. Because stem cells have interesting features closely mirroring circuit reprogramming, they are used as the first system for monitoring and interrogating reactions in the network of pathways. Viral infection and cancer cells will be used in drug combinatorial studies. As the program becomes more mature, networks of all three systems will be interrogated by nano tools under the potent drug cocktails.
partnership of UCLA, UC Riverside, UC Merced, USC, and Caltech.

The center’s current research portfolio encompasses projects across nine technology and applications areas, examples of which include

- development and deployment of new measurement tools and techniques to identify the sources and fates of chemical and biological pollutants in natural, urban, and agricultural watersheds and coastal zones
- development of cameras and image analysis approaches that assist scientists in making biological observations. Together, the camera and analysis systems comprise a new type of biosensor that takes measurements otherwise unobservable to humans
- harnessing the technological power of mobile phones and the ubiquitous wireless infrastructure for applications in areas as diverse as public health, environmental protection, urban planning, and cultural expression, each of which is influenced by independent personal behaviors adding up in space and time

Molecularly Engineered Energy Materials Energy Frontier Research Center

U.S. Department of Energy, Office of Science, Basic Energy Sciences

Vidvuds Ozolins, Ph.D. (Materials Science and Engineering), Director

The interdisciplinary Molecularly Engineered Energy Materials (MEEM) Energy Frontier Research Center (EFRC) was established in 2009 and brings together several faculty across the UCLA campus in close collaboration with scientists and faculty at the Department of Energy’s National Renewable Energy Laboratory, Eastern Washington University, the University of Kansas, and UC Berkeley.

MEEM has active research programs on organic solar cells, electrochemical supercapacitors, and materials for carbon capture. MEEM focuses on materials that are inherently inexpensive (such as polymers, oxides, and metal-organic frameworks), can be easily assembled from intelligently 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.

Center on Functional Engineered Nano Architectonics

Microelectronic Advanced Research Corporation Focus Center

Kang L. Wang, Ph.D. (Electrical Engineering), Director; Bruce S. Dunn, Ph.D. (Materials Science and Engineering), Co-Director; http://www.fena.org

Dramatic advances in nanotechnology, molecular electronics, and quantum computing are creating the potential for significant expansion of current semiconductor technologies. Researchers at UCLA make pioneering contributions to these fields through the Functional Engineered Nano Architectonics Focus Center (FENA) funded by the Semiconductor Research Association and the Department of Defense.

The term ‘architectonics’ is derived from a Greek word meaning master builder—an apt description of the center’s researchers as they build a new generation of nanoscale materials, structures, and devices for the electronics industry.

The FENA team explores the challenges facing the semiconductor industry as the electronic devices and circuits that power today’s computers grow ever smaller. With more and more transistors and other components squeezed onto a single chip, manufacturers are rapidly approaching the physical limits posed by current chip-making processes. Researchers seek to resolve a number of issues related to post-CMOS technologies that allow them to extend semiconductor technology further into the realm of the nanoscale.

Western Institute of Nanoelectronics

A Nanoelectronics Research Initiative National Institute of Excellence

Kang L. Wang, Ph.D. (Electrical Engineering), Director; http://win-nano.org

The Western Institute of Nanoelectronics (WIN), one of the world’s largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically-needed innovations in semiconductor technology.

A National Institute of Excellence, WIN leverages what are considered the best interdisciplinary nanoelectronics talents in the world to explore and develop advanced research devices, circuits, and nanosystems with performance beyond conventional CMOS devices. The pioneering new technology of spintronics relies on the spin of an electron to carry information, and holds promise in minimizing power consumption for next-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.
# B.S. in Aerospace Engineering Curriculum

## Freshman Year

<table>
<thead>
<tr>
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<th>Course</th>
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<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A ó Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L ó Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Physics 1A ó Mechanics</td>
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## Sophomore Year

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<td>Physics 1B ó Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>Physics 4AL ó Electricity and Magnetism Laboratory</td>
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<td>Mechanical and Aerospace Engineering 102 ó Dynamics of Particles and Rigid Bodies</td>
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<td>Mechanical and Aerospace Engineering 182A ó Mathematics of Engineering</td>
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<td>Mechanical and Aerospace Engineering 107 ó Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>Mechanical and Aerospace Engineering 150A ó Intermediate Fluid Mechanics</td>
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<td>Mechanical and Aerospace Engineering 157S ó Basic Aerospace Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 150B ó Aerodynamics</td>
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<td>Mechanical and Aerospace Engineering 171A ó Introduction to Feedback and Control Systems</td>
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## Senior Year

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<td>1st</td>
<td>Mechanical and Aerospace Engineering 154S ó Flight Mechanics, Stability, and Control of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 155 ó Aircraft Propulsion Systems</td>
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<td>Mechanical and Aerospace Engineering 166A ó Analysis of Flight Structures</td>
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<td>Mechanical and Aerospace Engineering 166A ó Analysis of Flight Structures</td>
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<td>Mechanical and Aerospace Engineering 154A ó Preliminary Design of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 154B ó Design of Aerospace Structures</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 20 for details).†A total of 8 units of aerospace engineering electives (two courses) is required.
# B.S. in Bioengineering 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>Chemistry and Biochemistry 20L * General Chemistry Laboratory</td>
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## SOPHOMORE YEAR

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<td>Bioengineering 100 * Bioengineering Fundamentals</td>
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<td>Life Sciences 2 * Cells, Tissues, and Organs</td>
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<td>Mathematics 33A * Linear Algebra and Applications</td>
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<td>Physics 4BL * Electricity and Magnetism Laboratory</td>
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<td>Bioengineering 182A * Bioengineering Capstone Design I</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>Mathematics 32B * Differential Equations</td>
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## JUNIOR YEAR

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<td>Electrical Engineering 100 * Electrical and Electronic Circuits</td>
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<td>Bioengineering 120 * Biomedical Transducers</td>
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<td>Life Sciences 3 * Introduction to Molecular Biology</td>
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<td>Bioengineering 110 * Biotransport and Bioreaction Processes</td>
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<td>Bioengineering 176 * Principles of Biocompatibility</td>
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<td>Computer Science 31 * Introduction to Computer Science I</td>
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<td>Life Sciences 4 * Genetics</td>
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## SENIOR YEAR

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<td>Bioengineering M106 * Topics in Biophysics, Channels, and Membranes</td>
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<td>Bioengineering 182B * Bioengineering Capstone Design II</td>
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<td>2nd</td>
<td>Bioengineering 180 * System Integration in Biology, Engineering, and Medicine</td>
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<td>Bioengineering 182C * Bioengineering Capstone Design III</td>
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<td><strong>TOTAL 187</strong></td>
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*Students should consult the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).

**Satisfies the HSSEAS ethics requirement.

# B.S. in Chemical Engineering Curriculum

## FRESHMAN YEAR

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<tr>
<th>Quarter</th>
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<td>Chemistry and Biochemistry 20A ó</td>
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<td>Mathematics 31A ó</td>
<td>Differential and Integral Calculus</td>
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<td>Mathematics 31B ó</td>
<td>Integration and Infinite Series</td>
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<td>Physics 1A ó</td>
<td>Mechanics</td>
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<td>Chemistry and Biochemistry 20B ó</td>
<td>Chemical Energetics and Change</td>
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<td>Computer Science 31 ó</td>
<td>Introduction to Computer Science I</td>
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## SOPHOMORE YEAR

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<td>Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>General Chemistry Laboratory II</td>
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<td>Physics 1C/4BL ó</td>
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<td>Chemical Engineering 102A ó</td>
<td>Thermodynamics I</td>
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<td>Chemistry and Biochemistry 30B ó</td>
<td>Organic Chemistry I: Structure and Reactivity</td>
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<td>Mathematics 33A ó</td>
<td>Linear Algebra and Applications</td>
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<td>Chemical Engineering 102B ó</td>
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## JUNIOR YEAR

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<td>Chemical Engineering 101A ó</td>
<td>Transport Phenomena I</td>
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<td>Chemical Engineering 109 ó</td>
<td>Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>2nd Quarter</td>
<td>Chemical Engineering 101B ó</td>
<td>Transport Phenomena II: Heat Transfer</td>
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<td>Chemistry and Biochemistry 113A ó</td>
<td>Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 101C ó</td>
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<td>Chemical Engineering 104AL ó</td>
<td>Chemical and Biomolecular Engineering Laboratory I</td>
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<td>Chemistry and Biochemistry 153A ó</td>
<td>Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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## SENIOR YEAR

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<td>Chemical and Biomolecular Engineering Laboratory II</td>
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<td>Chemical Engineering 106 ó</td>
<td>Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107 ó</td>
<td>Process Dynamics and Control</td>
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<td>Chemical Engineering 108A ó</td>
<td>Process Economics and Analysis</td>
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<td>Chemical Engineering 108B ó</td>
<td>Chemical Process Computer-Aided Design and Analysis</td>
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**TOTAL** 186

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).
### B.S. in Chemical Engineering Biomedical Engineering Option Curriculum

#### FRESHMAN YEAR

**1st Quarter**
- Chemical Engineering 10 ó Introduction to Chemical and Biomolecular Engineering. ................................................................. 1
- Chemistry and Biochemistry 20A ó Chemical Structure ................................................................. 4
- English Composition 3 ó English Composition, Rhetoric, and Language ................................................................. 5
- Mathematics 31A ó Differential and Integral Calculus ................................................................. 4

**2nd Quarter**
- Chemistry and Biochemistry 20B ó Chemical Energetics and Change ................................................................. 4
- Computer Science 31 ó Introduction to Computer Science I ................................................................. 4
- Mathematics 31B ó Integration and Infinite Series ................................................................. 4
- Physics 1A ó Mechanics ................................................................. 5

**3rd Quarter**
- Chemistry and Biochemistry 20L ó General Chemistry Laboratory ................................................................. 3
- Chemistry and Biochemistry 30A ó Organic Chemistry I: Structure and Reactivity ................................................................. 4
- Mathematics 32A ó Calculus of Several Variables ................................................................. 4
- Physics 1B/4AL ó Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory ................................................................. 7

#### SOPHOMORE YEAR

**1st Quarter**
- Chemical Engineering 100 ó Fundamentals of Chemical and Biomolecular Engineering ................................................................. 4
- Chemistry and Biochemistry 30AL ó General Chemistry Laboratory II ................................................................. 4
- Mathematics 32B ó Calculus of Several Variables ................................................................. 4
- Physics 1C ó Electrodynamics, Optics, and Special Relativity ................................................................. 5

**2nd Quarter**
- Chemical Engineering 102A ó Thermodynamics I ................................................................. 4
- Chemistry and Biochemistry 30B ó Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy ................................................................. 4
- Mathematics 33A ó Linear Algebra and Applications ................................................................. 4
- HSSEAS GE Elective* ................................................................. 5

**3rd Quarter**
- Chemical Engineering 102B ó Thermodynamics II ................................................................. 4
- Mathematics 33B ó Differential Equations ................................................................. 4
- HSSEAS GE Elective* ................................................................. 5

#### JUNIOR YEAR

**1st Quarter**
- Chemical Engineering 101A ó Transport Phenomena I ................................................................. 4
- Chemical Engineering 109 ó Numerical and Mathematical Methods in Chemical and Biological Engineering ................................................................. 4
- Life Sciences 2 ó Cells, Tissues, and Organs ................................................................. 5

**2nd Quarter**
- Chemical Engineering 101B ó Transport Phenomena II: Heat Transfer ................................................................. 4
- Chemistry and Biochemistry 113A ó Physical Chemistry: Introduction to Quantum Mechanics ................................................................. 4
- Life Sciences 3 ó Introduction to Molecular Biology ................................................................. 5

**3rd Quarter**
- Chemical Engineering 101C ó Mass Transfer ................................................................. 4
- Chemical Engineering 103 ó Separation Processes ................................................................. 4
- Chemical Engineering 104AL ó Chemical and Biomolecular Engineering Laboratory I ................................................................. 4
- Chemistry and Biochemistry 153A ó Biochemistry: Introduction to Structure, Enzymes, and Metabolism ................................................................. 4

#### SENIOR YEAR

**1st Quarter**
- Chemical Engineering 104B ó Chemical and Biomolecular Engineering Laboratory II ................................................................. 6
- Chemical Engineering 106 ó Chemical Reaction Engineering ................................................................. 4
- Technical Breadth Course* ................................................................. 4

**2nd Quarter**
- Chemical Engineering 107 ó Process Dynamics and Control ................................................................. 4
- Chemical Engineering 108A ó Process Economics and Analysis ................................................................. 4
- HSSEAS Ethics Course ................................................................. 4
- Technical Breadth Course* ................................................................. 4

**3rd Quarter**
- Chemical Engineering 108B ó Chemical Process Computer-Aided Design and Analysis ................................................................. 4
- HSSEAS GE Electives (2)* ................................................................. 10
- Technical Breadth Course* ................................................................. 4

**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 20 for details).
## B.S. in Chemical Engineering
### Biomolecular Engineering Option Curriculum

### Freshman Year

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### Sophomore Year

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<td>Chemistry and Biochemistry 113A ó</td>
<td>Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 125 ó</td>
<td>Bioseparations and Bioprocess Engineering</td>
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<td>Chemistry and Biochemistry 153A ó</td>
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### Senior Year

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<td>Chemical Engineering 108A ó</td>
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<td>Chemical Engineering 108B ó</td>
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# B.S. in Chemical Engineering
## Environmental Engineering Option Curriculum

### FRESHMAN YEAR

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<td>Chemical Engineering 10 ó · Introduction to Chemical and Biomolecular Engineering</td>
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<tr>
<td>Mathematics 31A ó · Differential and Integral Calculus</td>
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<tr>
<td>Chemistry and Biochemistry 20B ó · Chemical Energetics and Change</td>
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<td>Computer Science 31 ó · Introduction to Computer Science I</td>
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<tr>
<td>Physics 1A ó · Mechanics</td>
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#### 3rd Quarter

<table>
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<tbody>
<tr>
<td>Chemistry and Biochemistry 20L ó · General Chemistry Laboratory</td>
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<td>Chemistry and Biochemistry 30A ó · Organic Chemistry I: Structure and Reactivity</td>
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<tr>
<td>Mathematics 32B ó · Calculus of Several Variables</td>
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<tr>
<td>Physics 1B/4AL ó · Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<tr>
<td>Mathematics 32A ó · Linear Algebra and Applications</td>
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### SOPHOMORE YEAR

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<tbody>
<tr>
<td>Chemical Engineering 100 ó · Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Physics 1C/4BL ó · Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<tr>
<td>Chemical Engineering 102A ó · Thermodynamics I</td>
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<tr>
<td>Chemistry and Biochemistry 30B ó · Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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#### 3rd Quarter

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<tbody>
<tr>
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<td>Mathematics 31B ó · Integration and Infinite Series</td>
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### JUNIOR YEAR

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<td>Atmospheric and Oceanic Sciences 104 ó · Fundamentals of Air and Water Pollution</td>
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<td>Chemical Engineering 101A ó · Transport Phenomena I</td>
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<td>Chemical Engineering 109 ó · Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101B ó · Transport Phenomena II: Heat Transfer</td>
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<tr>
<td>Chemistry and Biochemistry 113A ó · Physical Chemistry: Introduction to Quantum Mechanics</td>
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#### 3rd Quarter

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<th>Course</th>
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<tbody>
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<td>Chemical Engineering 101C ó · Mass Transfer</td>
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<td>Chemical Engineering 103 ó · Separation Processes</td>
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<td>Chemical Engineering 104AL ó · Chemical and Biomolecular Engineering Laboratory I</td>
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<tr>
<td>Chemistry and Biochemistry 153A ó · Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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### SENIOR YEAR

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<td>Chemical Engineering 106 ó · Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107 ó · Process Dynamics and Control</td>
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#### 3rd Quarter

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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 20 for details).
# B.S. in Chemical Engineering
## Semiconductor Manufacturing Engineering Option Curriculum

### Freshman Year

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### Senior Year

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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
<td>Chemical Engineering 106 ó Chemical Reaction Engineering</td>
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<tr>
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<td>Electrical Engineering or Materials Science and Engineering Electives (2)</td>
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<tr>
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<td>Technical Breadth Course*</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
<td>Chemical Engineering 107 ó Process Dynamics and Control</td>
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<td>Chemical Engineering 108A ó Process Economics and Analysis</td>
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<td>HSSEAS Ethics Course</td>
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<td></td>
<td>Technical Breadth Course*</td>
<td>4</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
<td>Chemical Engineering 104C/104CL ó Semiconductor Processing/Laboratory</td>
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<td>Chemical Engineering 108B ó Chemical Process Computer-Aided Design and Analysis</td>
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<td>Chemical Engineering C116 ó Surface and Interface Engineering</td>
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<td>Technical Breadth Course*</td>
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</table>

**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 20 for details).*
# B.S. in Civil Engineering Curriculum

## Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A ó Chemical Structure</td>
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<td>Civil and Environmental Engineering 1 ó Introduction to Civil Engineering</td>
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<tr>
<td></td>
<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
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<tr>
<td></td>
<td>Mathematics 31A ó Differential and Integral Calculus</td>
<td>4</td>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L ó Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B ó Integration and Infinite Series</td>
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<tr>
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<td>Physics 1A ó Mechanics</td>
<td>5</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Mathematics 32A ó Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td></td>
<td>Physics 1B ó Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>Physics 4AL ó Mechanics Laboratory</td>
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## Sophomore Year

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<tbody>
<tr>
<td>1st Quarter</td>
<td>Civil and Environmental Engineering 101 ó Statics and Dynamics</td>
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<td>Mathematics 32B ó Calculus of Several Variables</td>
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<tr>
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<td>Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)</td>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td>2nd Quarter</td>
<td>Civil and Environmental Engineering 15 ó Introduction to Computing for Civil Engineers</td>
<td>2</td>
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<td></td>
<td>Civil and Environmental Engineering 108 ó Introduction to Mechanics of Deformable Solids</td>
<td>4</td>
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<tr>
<td></td>
<td>Computer Science 31 ó Introduction to Computer Science I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mathematics 33A ó Linear Algebra and Applications</td>
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<tr>
<td>3rd Quarter</td>
<td>Civil and Environmental Engineering 103 ó Applied Numerical Computing and Modeling in Civil and Environmental Engineering</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 104 ó Science of Engineering Materials</td>
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<td></td>
<td>Mathematics 33B ó Differential Equations</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 103 ó Elementary Fluid Mechanics</td>
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## Junior Year

<table>
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<tbody>
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<td>Civil and Environmental Engineering 120 ó Principles of Soil Mechanics</td>
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<td>Civil and Environmental Engineering 135A ó Elementary Structural Analysis</td>
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<td>Civil and Environmental Engineering 150 ó Introduction to Hydrology</td>
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<td>Civil and Environmental Engineering 153 ó Introduction to Environmental Engineering Science</td>
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<td>2nd Quarter</td>
<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Mechanical and Aerospace Engineering 182A ó Mathematics of Engineering</td>
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<td>HSSEAS Ethics Course</td>
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<td></td>
<td>Major Field Elective†</td>
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<td>3rd Quarter</td>
<td>Civil and Environmental Engineering 110 ó Introduction to Probability and Statistics for Engineers</td>
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<td>Major Field Electives (2)†</td>
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## Senior Year

<table>
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<th>Course</th>
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<tbody>
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<td>1st Quarter</td>
<td>HSSEAS GE Elective*</td>
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<tr>
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<td>Major Field Electives (2)†</td>
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<td>Technical Breadth Course*</td>
<td>4</td>
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<tr>
<td>2nd Quarter</td>
<td>HSSEAS GE Elective*</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Major Field Electives (2)†</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Technical Breadth Course*</td>
<td>4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>HSSEAS GE Elective*</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Major Field Electives (2)†</td>
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</tr>
</tbody>
</table>

**Total** 188, 189, or 190

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).† Must include required courses for two of the major field areas listed on page 46.
**B.S. in Computer Science Curriculum**

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Chemistry and Biochemistry 20A ó Chemical Structure</td>
<td>4</td>
</tr>
<tr>
<td>Computer Science 1 ó Freshman Computer Science Seminar</td>
<td>1</td>
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<tr>
<td>Computer Science 31 ó Introduction to Computer Science I</td>
<td>4</td>
</tr>
<tr>
<td>Mathematics 31A ó Differential and Integral Calculus</td>
<td>4</td>
</tr>
<tr>
<td>Computer Science 32 ó Introduction to Computer Science II</td>
<td>4</td>
</tr>
<tr>
<td><strong>2nd Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
<td>5</td>
</tr>
<tr>
<td>Mathematics 31B ó Integration and Infinite Series</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1A ó Mechanics</td>
<td>5</td>
</tr>
<tr>
<td><strong>3rd Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Computer Science 33 ó Introduction to Computer Organization</td>
<td>5</td>
</tr>
<tr>
<td>Mathematics 32A ó Calculus of Several Variables</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1B ó Oscillations, Waves, Electric and Magnetic Fields</td>
<td>5</td>
</tr>
<tr>
<td>Physics 4AL ó Mechanics Laboratory</td>
<td>2</td>
</tr>
</tbody>
</table>

**SOPHOMORE YEAR**

| **1st Quarter** |       |
| Computer Science 35L ó Software Construction Laboratory | 2 |
| Electrical Engineering 1 ó Electrical Engineering Physics I | 4 |
| Mathematics 32B ó Calculus of Several Variables | 4 |
| Physics 4BL ó Electricity and Magnetism Laboratory | 2 |
| HSSEAS GE Elective* | 5 |
| **2nd Quarter** |       |
| Computer Science M51A or Electrical Engineering M16 ó Logic Design of Digital Systems | 4 |
| Mathematics 33A ó Linear Algebra and Applications | 4 |
| Mathematics 61 ó Introduction to Discrete Structures | 4 |
| HSSEAS GE Elective* | 5 |
| **3rd Quarter** |       |
| Computer Science 131 ó Programming Languages | 4 |
| Computer Science M152A or Electrical Engineering M116L ó Introductory Digital Design Laboratory | 2 |
| Mathematics 33B ó Differential Equations | 4 |
| HSSEAS GE Elective* | 5 |

**JUNIOR YEAR**

| **1st Quarter** |       |
| Computer Science M151B or Electrical Engineering M116C ó Computer Systems Architecture | 4 |
| Computer Science 180 ó Introduction to Algorithms and Complexity | 4 |
| Computer Science Elective | 4 |
| HSSEAS GE Elective* | 4 |
| **2nd Quarter** |       |
| Computer Science 111 ó Operating Systems Principles | 5 |
| Computer Science Elective | 4 |
| HSSEAS Ethics Course | 4 |
| Science and Technology Elective | 4 |
| **3rd Quarter** |       |
| Computer Science 130 (Software Engineering) or 152B (Digital Design Project Laboratory) | 4 |
| Statistics 100A ó Introduction to Probability | 4 |
| HSSEAS GE Elective* | 5 |
| Technical Breadth Course* | 4 |

**SENIOR YEAR**

| **1st Quarter** |       |
| Computer Science 118 ó Computer Network Fundamentals | 4 |
| Computer Science 181 ó Introduction to Formal Languages and Automata Theory | 4 |
| Computer Science Elective | 4 |
| Technical Breadth Course* | 4 |
| **2nd Quarter** |       |
| Computer Science Elective | 4 |
| Science and Technology Elective | 4 |
| Technical Breadth Course* | 4 |
| **3rd Quarter** |       |
| Computer Science Electives (2) | 8 |
| Science and Technology Elective | 4 |

**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 20 for details).
# B.S. in Computer Science and Engineering Curriculum

## FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A</td>
<td>Chemical Structure</td>
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</tr>
<tr>
<td>1st Quarter</td>
<td>Computer Science 1</td>
<td>Freshman Computer Science Seminar</td>
<td>1</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>Computer Science 31</td>
<td>Introduction to Computer Science I</td>
<td>4</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>Mathematics 31A</td>
<td>Differential and Integral Calculus</td>
<td>4</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>Computer Science 32</td>
<td>Introduction to Computer Science II</td>
<td>4</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>English Composition 3</td>
<td>English Composition, Rhetoric, and Language</td>
<td>5</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>Mathematics 31B</td>
<td>Integration and Infinite Series</td>
<td>4</td>
</tr>
<tr>
<td>1st Quarter</td>
<td>Physics 1A</td>
<td>Mechanics</td>
<td>5</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Computer Science 33</td>
<td>Introduction to Computer Organization</td>
<td>5</td>
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<tr>
<td>2nd Quarter</td>
<td>Mathematics 32A</td>
<td>Calculus of Several Variables</td>
<td>4</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Physics 1B</td>
<td>Oscillations, Waves, Electric and Magnetic Fields</td>
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<tr>
<td>2nd Quarter</td>
<td>Physics 4AL</td>
<td>Mechanics Laboratory</td>
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</tr>
<tr>
<td>3rd Quarter</td>
<td>Computer Science M152A or Electrical Engineering M116L</td>
<td>Introductory Digital Design Laboratory</td>
<td>2</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 2</td>
<td>Physics for Electrical Engineers</td>
<td>4</td>
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<tr>
<td>3rd Quarter</td>
<td>Mathematics 33B</td>
<td>Differential Equations</td>
<td>4</td>
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<tr>
<td>3rd Quarter</td>
<td>Statistics 100A</td>
<td>Introduction to Probability</td>
<td>4</td>
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## SOPHOMORE YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science M51A or Electrical Engineering M16</td>
<td>Logic Design of Digital Systems</td>
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<tr>
<td>1st Quarter</td>
<td>Mathematics 33A</td>
<td>Linear Algebra and Applications</td>
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<tr>
<td>1st Quarter</td>
<td>Mathematics 61</td>
<td>Introduction to Discrete Structures</td>
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<tr>
<td>1st Quarter</td>
<td>HSSEAS GE Elective*</td>
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<td>Computer Science M152B</td>
<td>Calculus of Several Variables</td>
<td>4</td>
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<td>HSSEAS GE Elective*</td>
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<td>5</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering 1</td>
<td>Electrical Engineering Physics I</td>
<td>4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Computer Science M152A or Electrical Engineering M116L</td>
<td>Introductory Digital Design Laboratory</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 2</td>
<td>Physics for Electrical Engineers</td>
<td>4</td>
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<td>Mathematics 33B</td>
<td>Differential Equations</td>
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<tr>
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<td>Statistics 100A</td>
<td>Introduction to Probability</td>
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## JUNIOR YEAR

<table>
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<tr>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science 131</td>
<td>Programming Languages</td>
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<td>Computer Science M151B or Electrical Engineering M116C</td>
<td>Computer Systems Architecture</td>
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<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 10</td>
<td>Circuit Analysis I</td>
<td>4</td>
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<td>HSSEAS Ethics Course</td>
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<tr>
<td>2nd Quarter</td>
<td>Computer Science 111</td>
<td>Operating Systems Principles</td>
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<td>Computer Science 180</td>
<td>Introduction to Algorithms and Complexity</td>
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<td>Electrical Engineering 102</td>
<td>Systems and Signals</td>
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<td>2nd Quarter</td>
<td>Electrical Engineering 110</td>
<td>Circuit Analysis II</td>
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<td>Computer Science 181</td>
<td>Introduction to Formal Languages and Automata Theory</td>
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<td>Electrical Engineering 110L</td>
<td>Circuit Measurements Laboratory</td>
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<tr>
<td>3rd Quarter</td>
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## SENIOR YEAR

<table>
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<th>Course Title</th>
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<tr>
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<td>Computer Science 118</td>
<td>Computer Network Fundamentals</td>
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<td>1st Quarter</td>
<td>Computer Science 152B</td>
<td>Digital Design Project Laboratory</td>
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<td>1st Quarter</td>
<td>Electrical Engineering 115A</td>
<td>Analog Electronic Circuits I</td>
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<td>1st Quarter</td>
<td>Electrical Engineering 115C</td>
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<td>1st Quarter</td>
<td>HSSEAS GE Elective*</td>
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<td>2nd Quarter</td>
<td>Electrical Engineering 115C</td>
<td>Digital Electronic Circuits</td>
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<td>2nd Quarter</td>
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<tr>
<td>2nd Quarter</td>
<td>Technical Breadth Course*</td>
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<td>4</td>
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</table>

**TOTAL** 188

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).*
# B.S. in Electrical Engineering Curriculum

**FRESHMAN YEAR**

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A ó Chemical Structure.</td>
<td>4</td>
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<td>Computer Science 31 ó Introduction to Computer Science I.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mathematics 31A ó Differential and Integral Calculus.</td>
<td>4</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Computer Science 32 ó Introduction to Computer Science II.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>English Composition 3 ó English Composition, Rhetoric, and Language.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mathematics 31B ó Integration and Infinite Series.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Physics 1A ó Mechanics .</td>
<td>5</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 3 ó Introduction to Electrical Engineering.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Mathematics 32A ó Calculus of Several Variables.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Physics 1B ó Oscillations, Waves, Electric and Magnetic Fields.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Physics 4AL ó Mechanics Laboratory.</td>
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**SOPHOMORE YEAR**

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 10 ó Circuit Analysis I.</td>
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</tr>
<tr>
<td></td>
<td>Mathematics 32B ó Calculus of Several Variables.</td>
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</tr>
<tr>
<td></td>
<td>Mathematics 33A ó Linear Algebra and Applications.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Physics 4BL ó Electricity and Magnetism Laboratory.</td>
<td>2</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering 102 ó Systems and Signals.</td>
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</tr>
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<td></td>
<td>Electrical Engineering 110 ó Circuit Analysis II.</td>
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</tr>
<tr>
<td></td>
<td>Mathematics 33B ó Differential Equations.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>HSSEAS GE Elective*</td>
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</tr>
<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering M16 or Computer Science M51A ó Logic Design of Digital Systems</td>
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<tr>
<td></td>
<td>Electrical Engineering 103 ó Applied Numerical Computing.</td>
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<tr>
<td></td>
<td>Electrical Engineering 110L ó Circuit Measurements Laboratory.</td>
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<td>HSSEAS GE Elective*</td>
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**JUNIOR YEAR**

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<tr>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 1 ó Electrical Engineering Physics I.</td>
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<td>Electrical Engineering 113 ó Digital Signal Processing.</td>
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<tr>
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<td>Electrical Engineering 115A ó Analog Electronic Circuits I.</td>
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<tr>
<td></td>
<td>Electrical Engineering 131A ó Probability.</td>
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<td>2nd Quarter</td>
<td>Electrical Engineering 2 ó Physics for Electrical Engineers.</td>
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<td>Electrical Engineering 101 ó Engineering Electromagnetics.</td>
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<td>Electrical Engineering 115AL ó Analog Electronics Laboratory.</td>
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<td></td>
<td>Electrical Engineering 132A ó Introduction to Communication Systems.</td>
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<td>Statistics 105 ó Statistics for Engineers.</td>
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<tr>
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<td>Electrical Engineering 121B ó Principles of Semiconductor Device Design</td>
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<td>Electrical Engineering 141 ó Principles of Feedback Control.</td>
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<td>Electrical Engineering 161 ó Electromagnetic Waves.</td>
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<td>HSSEAS Ethics Course.</td>
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**SENIOR YEAR**

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<td></td>
<td>Technical Breadth Course*</td>
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<td>Mathematics 132 ó Complex Analysis for Applications.</td>
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<td>HSSEAS GE Elective*</td>
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<td></td>
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<td>Pathway Design Course†</td>
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<td>Technical Breadth Course*/HSSEAS GE Elective*</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 20 for details).
†See page 74 for a list of approved pathways.
# B.S. in Electrical Engineering

## Biomedical Engineering Option Curriculum

### Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
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<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A ó Chemical Structure</td>
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<td>Computer Science 31 ó Introduction to Computer Science I</td>
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<tr>
<td></td>
<td>Mathematics 31A ó Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L ó Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31B ó Integration and Infinite Series</td>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 30A ó Organic Chemistry I: Structure and Reactivity</td>
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<td>Chemistry and Biochemistry 30AL ó General Chemistry Laboratory II</td>
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<td>Mathematics 32A ó Calculus of Several Variables</td>
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### Sophomore Year

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<td>Electrical Engineering M16 or Computer Science M51A ó Logic Design of Digital Systems</td>
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<td>Mathematics 32B ó Calculus of Several Variables</td>
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<td>Mathematics 33A ó Linear Algebra and Applications</td>
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<td>Physics 1B/4AL ó Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>Electrical Engineering 3 ó Introduction to Electrical Engineering</td>
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<td>Electrical Engineering 102 ó Systems and Signals</td>
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<td>Life Sciences 2 ó Cells, Tissues, and Organs</td>
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<td>Mathematics 33B ó Differential Equations</td>
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<td>Physics 4BL ó Electricity and Magnetism Laboratory</td>
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<td>Electrical Engineering 10 ó Circuit Analysis I</td>
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<td>Electrical Engineering 103 ó Applied Numerical Computing</td>
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<td>Life Sciences 3 ó Introduction to Molecular Biology</td>
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### Junior Year

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<td>Electrical Engineering 110 ó Circuit Analysis II</td>
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<td>Electrical Engineering 113 ó Digital Signal Processing</td>
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<tr>
<td></td>
<td>Electrical Engineering 131A ó Probability</td>
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<td>2nd Quarter</td>
<td>Electrical Engineering 101 ó Engineering Electromagnetics</td>
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<td></td>
<td>Electrical Engineering 110L ó Circuit Measurements Laboratory</td>
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<tr>
<td></td>
<td>Electrical Engineering 115A ó Analog Electronic Circuits I</td>
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<td>Statistics 105 ó Statistics for Engineers</td>
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<tr>
<td></td>
<td>Pathway Course (Electrical Engineering 132A ó Introduction to Communication Systems)†</td>
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<tr>
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<td>Electrical Engineering 2 ó Physics for Electrical Engineers</td>
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<td></td>
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<td>Pathway Course (Electrical Engineering 1410 ó Principles of Feedback Control)†</td>
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### Senior Year

<table>
<thead>
<tr>
<th>Quarter</th>
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<td>HSSEAS Ethics Course</td>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td></td>
<td>Pathway Laboratory Course†</td>
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<tr>
<td></td>
<td>Technical Breadth Course*</td>
<td>4</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Mathematics 132 ó Complex Analysis for Applications</td>
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<tr>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td></td>
<td>Technical Breadth Course*</td>
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<tr>
<td>3rd Quarter</td>
<td>HSSEAS GE Elective*</td>
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<td>Pathway Course (Electrical Engineering 176 ó Lasers in Biomedical Applications or Mechanical and Aerospace Engineering 105A ó Introduction to Engineering Thermodynamics)†</td>
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<td>Pathway Design Course†</td>
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**TOTAL 188**

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).
†See page 74 for the biomedical engineering pathway.
# B.S. in Electrical Engineering

**Computer Engineering Option Curriculum**

<table>
<thead>
<tr>
<th><strong>FRESHMAN YEAR</strong></th>
<th><strong>UNITS</strong></th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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</tr>
<tr>
<td>Chemistry and Biochemistry 20A ó Chemical Structure.</td>
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</tr>
<tr>
<td>Computer Science 31 ó Introduction to Computer Science I.</td>
<td>4</td>
</tr>
<tr>
<td>Mathematics 31A ó Differential and Integral Calculus.</td>
<td>4</td>
</tr>
<tr>
<td><strong>2nd Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Computer Science 32 ó Introduction to Computer Science II.</td>
<td>4</td>
</tr>
<tr>
<td>English Composition 3 ó English Composition, Rhetoric, and Language.</td>
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</tr>
<tr>
<td>Mathematics 31B ó Integration and Infinite Series</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1A ó Mechanics</td>
<td>5</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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</tr>
<tr>
<td>Computer Science 33 ó Introduction to Computer Organization.</td>
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</tr>
<tr>
<td>Electrical Engineering 3 ó Introduction to Electrical Engineering</td>
<td>2</td>
</tr>
<tr>
<td>Mathematics 32A ó Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td>Physics 1B ó Oscillations, Waves, Electric and Magnetic Fields.</td>
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<tr>
<th><strong>SOPHOMORE YEAR</strong></th>
<th><strong>UNITS</strong></th>
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<tbody>
<tr>
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<td>Electrical Engineering 10 ó Circuit Analysis I .</td>
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<td>Mathematics 32B ó Calculus of Several Variables</td>
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<tr>
<td>Mathematics 33A ó Linear Algebra and Applications</td>
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<tr>
<td>Physics 4AL ó Mechanics Laboratory</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Electrical Engineering 102 ó Systems and Signals.</td>
<td>4</td>
</tr>
<tr>
<td>Electrical Engineering 110 ó Circuit Analysis II.</td>
<td>4</td>
</tr>
<tr>
<td>Mathematics 33B ó Differential Equations.</td>
<td>4</td>
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<tr>
<td>Physics 4BL ó Electricity and Magnetism Laboratory</td>
<td>2</td>
</tr>
<tr>
<td><strong>3rd Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Electrical Engineering M16 or Computer Science M51A ó Logic Design of Digital Systems</td>
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<tr>
<td>Electrical Engineering 103 ó Applied Numerical Computing.</td>
<td>4</td>
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<tr>
<td>Electrical Engineering 110L ó Circuit Measurements Laboratory</td>
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<tr>
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<tr>
<td>Computer Science 35L ó Software Construction Laboratory</td>
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<td>Electrical Engineering 1 ó Electrical Engineering Physics I</td>
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<tr>
<td>Electrical Engineering 113 ó Digital Signal Processing</td>
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</tr>
<tr>
<td>Electrical Engineering 115A ó Analog Electronic Circuits I</td>
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<td>Electrical Engineering 131A ó Probability</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Electrical Engineering 2 ó Physics for Electrical Engineers</td>
<td>4</td>
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<tr>
<td>Electrical Engineering 101 ó Engineering Electromagnetics</td>
<td>4</td>
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<tr>
<td>Statistics 105 ó Statistics for Engineers</td>
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<tr>
<td>HSSEAS GE Elective*</td>
<td>5</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Electrical Engineering 115C ó Digital Electronic Circuits.</td>
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<tr>
<td>Pathway Course (Electrical Engineering 132A ó Introduction to Communication Systems or Computer Science M117 ó Computer Networks: Physical Layer)†</td>
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<tr>
<th><strong>SENIOR YEAR</strong></th>
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<tbody>
<tr>
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<td>Electrical Engineering M116C or Computer Science M151B ó Computer Systems Architecture</td>
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<td>Pathway Course (Computer Science 111 ó Operating Systems Principles)†</td>
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<td>Technical Breadth Course*/Pathway Laboratory Course†</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Mathematics 132 ó Complex Analysis for Applications</td>
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<tr>
<td>Pathway Course (Computer Science 131 ó Programming Languages or 132 ó Compiler Construction or 180 ó Introduction to Algorithms and Complexity)†</td>
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<tr>
<td>Electrical Engineering 132B (Data Communications and Telecommunication Networks) or Computer Science 118 (Computer Network Fundamentals).</td>
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<tr>
<td>Technical Breadth Course*/HSSEAS GE Elective*</td>
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</table>

**TOTAL** 188

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).
†See page 74 for the computer engineering pathway.
# B.S. in Materials Engineering Curriculum

## Freshman Year

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<th>Course Title</th>
<th>Units</th>
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<td>Chemistry and Biochemistry 20A ó Chemical Structure</td>
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<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
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<tr>
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<td>Materials Science and Engineering 10 ó Freshman Seminar: New Materials</td>
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<tr>
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<td>Mathematics 31A ó Differential and Integral Calculus</td>
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## Sophomore Year

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<th>Course Title</th>
<th>Units</th>
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<tr>
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<td>Mathematics 32B ó Calculus of Several Variables</td>
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<td>Physics 1C ó Oscillations, Waves, Electric and Magnetic Fields</td>
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## Junior Year

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<td>Chemical Engineering 105A ó Introduction to Engineering Thermodynamics</td>
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<td>Mathematics 33A ó Linear Algebra and Applications</td>
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## Senior Year

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## Total

| Units | 185 or 186 |

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details). †See counselor in 6426 Boelter Hall for details.
B.S. in Materials Engineering
Electronic Materials Option Curriculum

<table>
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<th>FRESHMAN YEAR</th>
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<td>1st Quarter</td>
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<tr>
<td>Chemistry and Biochemistry 20A ó Chemical Structure</td>
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<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
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<tr>
<td>Materials Science and Engineering 10 ó Freshman Seminar: New Materials</td>
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<td>Mathematics 31A ó Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L ó Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td>Mathematics 31B ó Integration and Infinite Series</td>
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<td>Physics 1A ó Mechanics</td>
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<td>Computer Science 31 ó Introduction to Computer Science I</td>
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<tr>
<td>Mathematics 32A ó Calculus of Several Variables</td>
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<tr>
<td>Physics 1B ó Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>Materials Science and Engineering 104 ó Science of Engineering Materials</td>
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<tr>
<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<tr>
<td>Mathematics 33A ó Linear Algebra and Applications</td>
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<tr>
<td>Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)</td>
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<tr>
<td>HSSEAS GE Elective*</td>
<td>4</td>
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<tr>
<td>2nd Quarter</td>
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<tr>
<td>Materials Science and Engineering 90L ó Physical Measurement in Materials Engineering</td>
<td>2</td>
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<tr>
<td>Mathematics 33B ó Differential Equations</td>
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<tr>
<td>Mechanical and Aerospace Engineering 101 ó Statics and Strength of Materials</td>
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<td>HSSEAS GE Elective*</td>
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<table>
<thead>
<tr>
<th>JUNIOR YEAR</th>
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<tr>
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<tr>
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<tr>
<td>Materials Science and Engineering 110/110L ó Introduction to Materials Characterization A/Laboratory</td>
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<tr>
<td>Materials Science and Engineering 130 ó Phase Relations in Solids</td>
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<tr>
<td>Electrical Engineering 101 ó Engineering Electromagnetics</td>
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<tr>
<td>Materials Science and Engineering 120 (Physics of Materials) or Electrical Engineering 2 (Physics for Electrical Engineers)</td>
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<tr>
<td>Materials Science and Engineering 122 ó Principles of Electronic Materials Processing</td>
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<tr>
<td>Technical Breadth Course*</td>
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<tr>
<td>3rd Quarter</td>
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<tr>
<td>Electrical Engineering 121B ó Principles of Semiconductor Device Design</td>
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<tr>
<td>Materials Science and Engineering 121/121L ó Materials Science of Semiconductors/Laboratory</td>
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<tr>
<td>Electronic Materials Elective†</td>
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<tr>
<td>HSSEAS Ethics Course</td>
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<thead>
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<tr>
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<tr>
<td>Electronic Materials Elective†</td>
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<tr>
<td>HSSEAS GE Elective*</td>
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<td>Technical Breadth Course*</td>
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<tr>
<td>Upper Division Mathematics Elective†</td>
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<tr>
<td>Materials Science and Engineering 131/131L ó Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<tr>
<td>Electronic Materials Elective†</td>
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<td>Electronic Materials Laboratory Course†</td>
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<td>Technical Breadth Course*</td>
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<tr>
<td>Materials Science and Engineering 140 ó Materials Selection and Engineering Design</td>
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<tr>
<td>Elective†</td>
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<tr>
<td>Electronic Materials Laboratory Course†</td>
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</table>

TOTAL 187 or 188

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).
†See counselor in 6426 Boelter Hall for details.
# B.S. in Mechanical Engineering Curriculum

## FRESHMAN YEAR

<table>
<thead>
<tr>
<th>1st Quarter</th>
<th>2nd Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry and Biochemistry 20A ó Chemical Structure</td>
<td>Mathematics 31A ó Differential and Integral Calculus</td>
</tr>
<tr>
<td>English Composition 3 ó English Composition, Rhetoric, and Language</td>
<td>Physics 1A ó Mechanics</td>
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## SOPHOMORE YEAR

<table>
<thead>
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<th>1st Quarter</th>
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<tbody>
<tr>
<td>Mathematics 32A ó Calculus of Several Variables</td>
<td>Computer Science 31 ó Introduction to Computer Science I</td>
</tr>
<tr>
<td>Mechanical and Aerospace Engineering 94 ó Introduction to Computer-Aided Design and Drafting</td>
<td>Physics 1C ó Electrodynamics, Optics, and Special Relativity</td>
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<tr>
<td>Physics 4BL ó Electricity and Magnetism Laboratory</td>
<td>Physics 4AL ó Mechanics Laboratory</td>
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## JUNIOR YEAR

<table>
<thead>
<tr>
<th>1st Quarter</th>
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<tbody>
<tr>
<td>Electrical Engineering 100 ó Electrical and Electronic Circuits</td>
<td>Mechanical and Aerospace Engineering 102 ó Dynamics of Particles and Rigid Bodies</td>
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<tr>
<td>Mechanical and Aerospace Engineering 102D ó Transport Phenomena</td>
<td>Mechanical and Aerospace Engineering 182A ó Mathematics of Engineering</td>
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## SENIOR YEAR

<table>
<thead>
<tr>
<th>1st Quarter</th>
<th>2nd Quarter</th>
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<tbody>
<tr>
<td>Mechanical and Aerospace Engineering 133A (Engineering Thermodynamics) or HSSEAS GE Elective*</td>
<td>Mechanical and Aerospace Engineering 162A ó Introduction to Feedback and Control Systems</td>
</tr>
<tr>
<td>Mechanical and Aerospace Engineering 171A ó Introduction to Feedback and Control Systems</td>
<td>Mechanical and Aerospace Engineering 162M ó Senior Mechanical Engineering Design</td>
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## TOTAL

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*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 20 for details).
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<th>Fall 2010</th>
<th>Winter 2011</th>
<th>Spring 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>First day for continuing students to check URSA at</td>
<td>June 9</td>
<td>October 26, 2010</td>
<td>February 2, 2011</td>
</tr>
<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 21</td>
<td>November 10</td>
<td>February 14</td>
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<tr>
<td>Registration fee payment deadline</td>
<td>September 20</td>
<td>December 20</td>
<td>March 18</td>
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<tr>
<td>QUARTER BEGINS</td>
<td>September 20</td>
<td>January 3, 2011</td>
<td>March 28</td>
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<tr>
<td>Instruction begins</td>
<td>September 23</td>
<td>January 3</td>
<td>March 28</td>
</tr>
<tr>
<td>Last day for undergraduates to ADD courses with per-course fee through URSA</td>
<td>October 15</td>
<td>January 21</td>
<td>April 15</td>
</tr>
<tr>
<td>Last day for undergraduates to DROP nonimpacted courses without a transcript notation (with per-transaction fee through URSA)</td>
<td>October 22</td>
<td>January 28</td>
<td>April 22</td>
</tr>
<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP) with per-transaction fee through URSA</td>
<td>November 5</td>
<td>February 11</td>
<td>May 6</td>
</tr>
<tr>
<td>Instruction ends</td>
<td>December 3</td>
<td>March 11</td>
<td>June 3</td>
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<tr>
<td>Final examinations</td>
<td>December 6-10</td>
<td>March 14-18</td>
<td>June 6-10</td>
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<tr>
<td>QUARTER ENDS</td>
<td>December 10</td>
<td>March 18</td>
<td>June 10</td>
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<tr>
<td>HSSEAS Commencement</td>
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<td>June 11</td>
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<tr>
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<td>November 11</td>
<td>January 17</td>
<td>May 30</td>
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<td>November 25-26</td>
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<td>December 30-31</td>
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<tr>
<td>Winter Campus Closure*</td>
<td>December 24-</td>
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<td>January 2</td>
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*Revised plan for winter holiday closure under review.

## Admission Calendar

<table>
<thead>
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<th>Fall 2010</th>
<th>Winter 2011</th>
<th>Spring 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filing period for undergraduate applications (file with UC Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)</td>
<td>November 1-30, 2009</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Last day to file application for graduate admission or readmission with complete credentials and application fee, with Graduate Admissions/Student and Academic Affairs, 1255 Murphy Hall, UCLA, Los Angeles, CA 90024-1428</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
</tr>
<tr>
<td>Reentering students eligible to enroll begin to receive URSA notification letter at their mailing address</td>
<td>June 11, 2010</td>
<td>October 29</td>
<td>February 4</td>
</tr>
<tr>
<td>Last day to file Undergraduate Application for Readmission form at 1113 Murphy Hall (late applicants pay a late fee)</td>
<td>August 13</td>
<td>November 2</td>
<td>February 25</td>
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