UCLA

HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE 2005-06

ANNOUNCEMENT
OCTOBER 1, 2005

UNIVERSITY OF CALIFORNIA,
LOS ANGELES

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Contents

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Cover image of the new Engineering Building courtesy of the Urban Simulation Team at UCLA (Bill Jepson, Director).

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

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" which UCLA may release and publish without the student's prior consent: name, address (local/mailing, permanent, and/or e-mail), telephone numbers, major field of study, dates of attendance, enrollment status, grade level, number of course units in which enrolled, degrees and honors received, the most recent previous educational institution attended, participation in officially recognized activities (including intercollegiate athletics), and the name, weight, and height of participants on intercollegiate athletic teams.

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 Enrollment and Degree Services, 1113 Murphy Hall.

Student records which 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 online *UCLA Campus 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) 825-3801 or inquire at Academic Record Services, 1134 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, 600 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.

In addition to the public information described above, information related to students' Social Security number, sex, and marital status, and the name(s), address(es), and telephone number(s) of their parents or next of kin are made available to the UCLA External Affairs Department for use in alumni, development, and public relations activities. To restrict the release of this additional information, complete a Request for External Affairs Information Restriction form available from Enrollment and Degree Services, 1113 Murphy Hall.

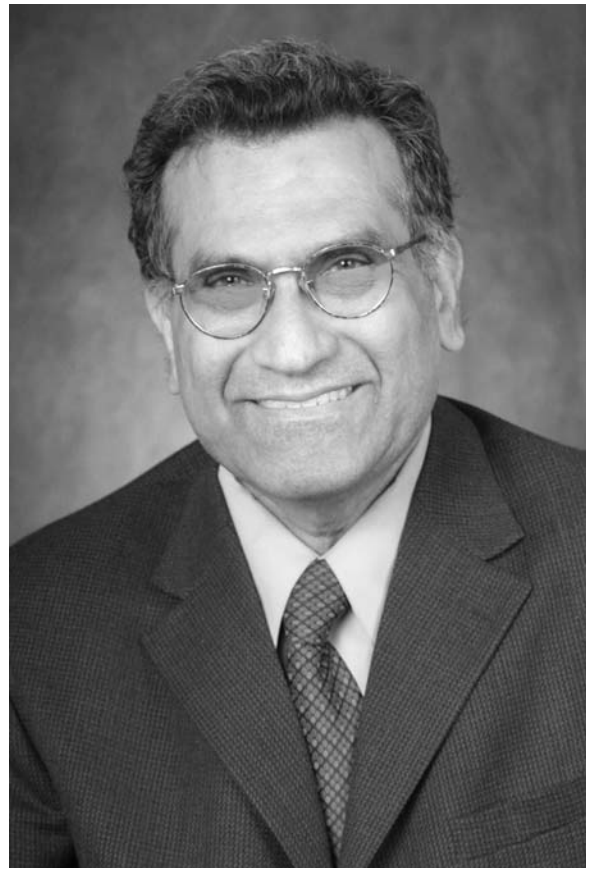
Academic Calendar

	Fall 2005	Winter 2006	Spring 2006
First day for continuing students to check URSA at http://www.ursa.ucla.edu for assigned enrollment appointments	June 15, 2005	November 2, 2005	February 7, 2006
URSA enrollment appointments begin	June 27	November 17	February 21
Late registration fee payment in person with $50 late fee	September 21	December 21	March 21
QUARTER BEGINS	September 26	January 4, 2006	March 29
Instruction begins	September 29	January 9	April 3
Last day for undergraduates to ADD courses with PTE number with $3 per course fee through URSA	October 21	January 27	April 21
Last day for undergraduates to DROP nonimpacted courses (without transcript notation) with $3 per transaction fee through URSA	October 28	February 3	April 28
Last day for undergraduates to change grading basis (optional P/NP) with $3 per transaction fee through URSA	November 10	February 17	May 12
Instruction ends	December 9	March 17	June 9
Final examinations	December 12-16	March 20-24	June 12-16
QUARTER ENDS	December 16	March 24	June 16
HSSEAS Commencement	—	—	June 17
Academic and administrative holidays	November 11 November 24-25 December 26-27 December 30-January 2	January 16 February 20	March 31 May 29 July 4

Admission Calendar

	Fall 2005	Winter 2006	Spring 2006
Filing period for undergraduate applications (file with UC Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)	November 1-30, 2004	—	—
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	Consult department	Consult department	Consult department
Reentering students eligible to enroll should begin to receive URSA notification letter at mailing address	June 10, 2005	November 7	February 10
Last day to file Undergraduate Application for Readmission form at 1113 Murphy Hall (late applicants pay a $50 late payment fee)	August 15	November 25	February 27

A Message from the Dean



Since it welcomed its first students 60 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 known as the birthplace of the Internet, the first reverse-osmosis membrane for the desalination of water, and other collaborative activities that have changed the way we think about the world around us.

Our faculty and students are leaders in new frontiers of applied science and engineering research, in areas such as information technology, embedded systems and senor networks, bioengineering, nanomanufacturing, and micro- and nanoelectromechanical systems.

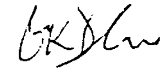
Located near the world-renowned David Geffen School of Medicine and the John E. Anderson Graduate School of Management, the School of Engineering is ideally situated to engage in interdisciplinary research and educational initiatives. The school also benefits from its proximity to the Los Angeles entertainment and media industries, Silicon Valley, the defense and aerospace industries, and a growing biotechnology sector.

To prepare our students for the ever-changing demands of the engineering profession, our curriculum focuses on ensuring that ensure our graduates receive an education with the breadth and depth they will need to succeed in their careers. Undergraduate student research opportunities are widely available and we encourage our students to take advantage of them.

In addition to working with individual faculty, students may also choose to participate in the school's world-class interdisciplinary research centers. These include the NSF Center for Embedded Networked Sensing, the NASA Institute for Cell Mimetic Space Exploration, the NSF Center for Scalable and Integrated Nanomanufacturing, the MARCO Functional Engineered Nano-Architectonics Focus Center, and the DARPA Center for Nanoscience Innovation for Defense. Our faculty and students are also active partners in the California NanoSystems Institute located at UCLA.

Our distinguished faculty is composed of recognized experts in their fields, including 21 members of the National Academy of Engineering, and many junior faculty who are widely honored 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 engineering, to society, and to industry. I invite you to consider becoming a UCLA engineer.



Vijay K. Dhir
Dean
Henry Samueli School of Engineering and Applied Science

Henry Samueli School of Engineering and Applied Science

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The Campus

UCLA is a large urban university situated between the city and the sea at the foot of the Santa Monica Mountains. Less than six miles from the Pacific, it is bordered by Sunset and Wilshire boulevards. As the city has grown physically and culturally, so has the campus, whose students and faculty mirror the cultural and racial diversity of today's Los Angeles. UCLA boasts broad vistas, landscaped gardens, and a blend of architectural styles ranging from Romanesque to modern. Campus moods vary from the activity of Bruin Walk to the serenity of the Japanese Garden.

UCLA is recognized as the West's leading center for the arts, culture, and medical research. Each year, more than half a million people attend visual and performing arts programs on campus, while more than 300,000 patients from around the world come to the UCLA Medical Center for treatment. The university has roughly 313 buildings on 419 acres that house the College of Letters and Science and 11 professional schools serving over 37,500 students. Nearly one in every 140 Californians holds a UCLA degree.

Today, 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 top administrative officer is Chancellor Albert Carnesale, the eighth chief executive in UCLA's 86-year history.

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

The School

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

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Center for Embedded Networked Sensing (CENS) develops embedded networked sensing systems and applies this revolutionary technology to critical scientific and social applications. Researchers in the Institute for Cell Mimetic Space Exploration (CMISE) identify, develop, promote, and commercialize nano-, bio-, and information technologies for sensing, control, and integration of complex natural and artificial systems. The Functional Engineered Nano-Architectonics Focus Center (FENA) leverages the latest advances in nanotechnology, molecular electronics, and quantum computing to extend semiconductor technology further into the realm of the nanoscale. The Center for Scalable and Integrated Nano-Manufacturing (SINAM) transforms laboratory science into industrial applications in nanoelectronics and biomedicine, creating the next generation of nanotools and systems that will enable cost-effective nanomanufacturing. The Center for Nanoscience Innovation for Defense (CNID) facilitates the rapid transition of research innovation in the nanosciences into applications for the defense sector. Finally, the California NanoSystems Institute (CNSI)–a joint endeavor with UC Santa Barbara–develops the information, biomedical, and manufacturing technologies of the twenty-first century.

In addition, the school has identified critical areas for collaborative research, including biomedical informatics; alternative energy solutions; secure electronic transfers of information; new tools for the entertainment industry; systems, dynamics, and controls; and advanced technologies for water reclamation.

The school offers 28 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. 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 24. 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 Doumani 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/Electromagnetics

Northrop Grumman Chair in Microwave and Millimeter Wave Electronics

Northrop Grumman Opto-Electronic Chair in Electrical Engineering

Ralph M. Parsons 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

Ben Rich Lockheed Martin Chair in Aeronautics

Rockwell International Chair in Engineering

William Frederick Seyer Term Chair in Materials Electrochemistry

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 systems technology.

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

The B.S. program in Aerospace Engineering emphasizes fundamental disciplines and therefore provides a solid base for professional career development in industry and graduate study in aerospace engineering. Graduate education, primarily at the Ph.D. level, 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 Engineering

Chemical engineers use their knowledge of mathematics, physics, chemistry, and biology to meet the needs of our technological society. They design, research, develop, operate, and manage the chemical and petroleum industries and are leaders in the fields of hazardous wastes control, environmental protection, biotechnology and biomedical engineering, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, food, paper, aerospace, automotive, 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 includes the design of chemical processes and reactors and 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,
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 system concepts. As a result, students at the B.S. level are qualified for employment as applications programmers, systems programmers, digital system designers, digital system marketing engineers, and project engineers.

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

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

Electrical Engineering

There are several fields of specialization, both theoretical and applied, within the electrical engineering discipline. The Electrical Engineering Department provides study and training in the areas of communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization/operations research, integrated circuits and systems, microelectromechanical systems/nanotechnology (MEMS/nano), photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. A brief description of each area is provided under Fields of Study on page 75. Each of the fields presents opportunities for employment to the electrical engineering graduate.

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. This includes computer-aided design and computer-aided manufacturing, robotics, metal forming and metal cutting analysis, nondestructive evaluation, and design and optimization of manufacturing processes.

Materials Engineering

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

Two programs within materials engineering are available at UCLA:

1. In the *materials engineering* program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries. Materials engineers are responsible for the selection and testing of materials for specific applications. Traditional fields of metallurgy and ceramics have been merged in industry, and this program reflects the change.
2. In the *electronic materials option* of the materials engineering program, students learn the basics of materials engineering with a concentration in electronic materials and processing. The optional program requires additional coursework which includes five to eight electrical engineering courses.

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

Mechanical Engineering

Mechanical engineering is a broad discipline finding application in virtually all industries and manufactured products. The mechanical engineer applies principles of mechanics, dynamics, and energy transfer to the design, analysis, testing, and manufacture of consumer and industrial products. A mechanical engineer usually has specialized knowledge in areas such as design, materials, fluid dynamics, solid dynamics, 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.

The mechanical engineer with a specialization in power systems and thermal design is concerned with energy utilization and thermal environment control. Design of power and propulsion systems (power plants, engines) and their components is a major activity. Thermal environment control requires the design of thermal control systems having heat pumps, heat pipes, heat exchangers, thermal insulation, and ablation heat shields. Heating, ventilation, air conditioning (HVAC), vacuum technology, cryogenics, and solar thermal energy are other areas in which the mechanical engineer contributes.

Mechanical engineers with a specialization in mechanical systems design and control and in manufacturing processes are the backbone of any industry. They participate in the conception, design, and manufacture of a commercial product as is found in the automotive, aerospace, chemical, or electronics industries. With specialization in fluids engineering, mechanical engineers gain breadth in aerodynamics and propulsion systems that allows them to become ideal candidates for employment in aerospace and other related 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.

Facilities and Services

Teaching and research facilities at HSSEAS are in Boelter Hall, Engineering I, and Engineering IV, located in the south of 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. Additional faculty offices and laboratories, the Shop Services Center, and the Student and Faculty Shop are in the Engineering I building.

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 7.6 million volumes, and more than 79,000 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

Collections and services of the Science and Engineering Library (SEL) support research and programs in all departments and related institutes of HSSEAS and the Physical Sciences Division, College of Letters and Science.

The SEL site in Boelter Hall houses the engineering, mathematics, statistics, astronomy, and atmospheric sciences collections; most public service staff and librarians; and divisions for administration, collection development and public services. Other SEL collections covering chemistry, geology-geophysics, and physics are housed in Young Hall and the Geology Building.

The SEL collection contains over 577,000 volumes, subscriptions to 5,251 current serials, and over 4,000,000 technical reports. "Questions? Ask Us" online live chat, e-mail, and in-person reference assistance is provided Monday through Friday.

Faculty, students, and staff can e-mail questions to the library at sel-ref@library.ucla.edu. Librarians are available to provide instruction for teaching assignments requiring the use of library resources.

The library provides access to a variety of resources, including e-journals, e-books, and article databases, in addition to paper equivalents. Copy machines, Internet printers, and microform readers/printers are available at each SEL location. Reserve, interlibrary loan, and document delivery, as well as other services and useful engineering and science resources, are featured on the SEL website. See http://www.library.ucla.edu/sel/.

Services

Instructional Computer Facility

HSSEAS maintains a network of 16 Sun Fire V120/V440 and Sun Enterprise 220/280 servers, 25 Sun Solaris Ultra 5 computers, six Dell Poweredge multi-processor Windows servers, two Network Appliance RAID NFS servers and four Linux RAID NFS servers connected to a high-speed backbone network. The machines function as cycle, file, and application servers to approximately 600 Unix and Microsoft Windows workstations. Four open computer laboratories and one classroom for computerized instruction house 210 of the PC workstations. Remote access to HSSEAS coursework applications is provided via Microsoft Terminal Server.

In addition, UCLA Academic Technology Services (ATS) operates a 40-node, dual-processor Beowulf cluster that is used for performing lengthy, numerically intensive computations and for programs that can utilize parallel computing resources. ATS also provides assistance to groups and individuals wishing to parallelize their codes or establish their own local Beowulf cluster.

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

Frank E. Burris, 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 141 annual offerings draws participants from around the world for two- to five-day intensive programs. The acclaimed Technical Management Program holds its seventieth offering in September 2005 and seventy-first in March 2006.

The Information Systems program–of fering 205 classes annually, including six certificate programs and four sequential programs in evening, day, weekend, and online formats–covers a br oad range of information technologies.

Each year, the department offers 130 classes in engineering disciplines that include manufacturing engineering, electrical engineering, astronautical engineering, construction management, and PE review classes. In addition, 91 technical management offerings complement the engineering offerings. Most engineering and technical management classes are in a quarter-length, evening format. Call (310) 825-3344 for short course programs, (310) 825-3858 for the Technical Management Program, (310) 825-4100 for information systems programs, and (310) 206-1548 for engineering or technical management classes, or fax (310) 206-2815. See http://www.uclaextension.edu.

Career Services

Engineering and Science Career Services

Engineering and Science Career Services, a branch of the UCLA Career Center, assists HSSEAS undergraduate and graduate students and alumni explore career possibilities, prepare for graduate and professional school, obtain employment and internship leads, and develop 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™ provides seniors and graduate students with opportunities to meet one-on-one with employers seeking entry-level job candidates and offers 24-hour access to hundreds of current full-time, part-time, seasonal, and internship positions. An annual career fair for HSSEAS students is held Fall Quarter, and HSSEAS students are also welcomed at all Career Center-sponsored job fairs.

The Career Center's Engineering and Science staff also provides consultation services to HSSEAS student organizations. Engineering and Science 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 only. For more information call (310) 206-1915 or see http://career.ucla.edu.

Ashe Student Health and Wellness Center

The Arthur Ashe Student Health and Wellness Center (Student Health Service) is the campus health service and an outpatient health facility for all registered UCLA students. Most services are subsidized by registration fees, but there are minimal fees for all services. Visit, core laboratory, and X-ray fees for students with the Student Health Insurance Plan (SHIP) are written off by SHIP. There are co-pays for pharmaceuticals. Service fees for students without SHIP are billed directly to students' BAR accounts.

If students withdraw during a term, the Ashe Center continues to be available for the remainder of the term on a full-fee basis from the date of withdrawal. If students withdraw with no refund, SHIP is maintained and services remain available as described above.

The cost of services received outside the Ashe Center is each student's financial responsibility. Students who waive out of the UCLA Student Health Insurance Plan (SHIP) need to ensure that they are enrolled in a plan adequate to cover expenses incurred outside of the Ashe Center.

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. Patients without appointments (walk-ins) are seen on the first floor. Patients with appointments are seen on the first, second, or third floor. Physical therapy and the insurance office are on the fourth floor. Located at 221 Westwood Plaza; see http://www.studenthealth.ucla.edu.

For emergency care when the Ashe Center is closed, students may obtain treatment at the UCLA Medical Center Emergency Room on a fee-for-service basis. It is the student's responsibility to have insurance billed.

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.saonet.ucla.edu/osd/.

Fees and Financial Support

Fees and Expenses

The 2005-06 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.

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

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

2005-06 ANNUAL UCLA GRADUATE AND UNDERGRADUATE FEES

Fees are subject to revision without notice

	Graduate Students		Undergraduate Students	
	Resident	Nonresident	Resident	Nonresident
University registration fee	$ 735.00	$ 735.00	$ 735.00	$ 735.00
Educational fee	6,162.00	6,429.00	5,406.00	5,922.00
Undergraduate Students Association fee			119.73	119.73
Graduate Students Association fee	39.00	39.00		
Ackerman Student Union fee	7.50	7.50	7.50	7.50
Seismic fee for Ackerman/Kerckhoff	113.00	113.00	113.00	113.00
Wooden Center fee	39.00	39.00	39.00	39.00
Student Programs, Activities, and Resources Complex fee	84.00	84.00	84.00	84.00
Mandatory medical insurance	930.00	930.00	558.00	558.00
Nonresident tuition		14,694.00		17,304.00
Total mandatory fees	$ 8,109.50	$ 23,070.50	$ 7,062.23	$ 24,882.23

Living Accommodations

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

The UCLA 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 the UCLA Housing Assignment Office, 360 De Neve Drive, Box 951381, Los Angeles, CA 90095-1381, (310) 825-4271; see http://www.housing.ucla.edu/myhousing/. Newly admitted students are sent *UCLA Housing*, which describes costs, locations, and eligibility for both private and UCLA-sponsored housing.

The Dashew International Center for Students and Scholars, 106 Bradley Hall, (310) 825-1981, http://www.intl.ucla.edu, provides personalized housing assistance for international students. Additionally, the center helps students adjust to the UCLA community and sponsors social activities.

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 2006-07 academic year is March 2, 2006. 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's financial aid program is available at the Financial Aid Office, A129J Murphy Hall, (310) 206-0400; see http://www.fao.ucla.edu.

Scholarships

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

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

The following scholarships are available only to HSSEAS undergraduates:

Altera Scholarship. For computer science, computer science and engineering, and electrical engineering students; four $4,750 scholarships

ARCO Products Company Scholarship. For students in chemical engineering

James W. Binns Scholarship. For a sophomore, junior, or senior in any HSSEAS major, with financial need and a 3.0 or higher GPA.

Eugene Birnbaum Scholarship. For sophomore engineering students with interest in research

Stanley Black Scholarship–Sponsored by the Jewish Community Foundation. For an engineering student with high academic achievement.

L.M.K. Boelter Scholarship Fund. For students in the field of engineering

Chevron U.S.A., Inc., Scholarship. For students in chemical engineering

Charles Martin Duke, Jr., Scholarship in Structural Engineering. For a junior in the field of structural engineering

Engineering Senior Gift. For a sophomore or junior HSSEAS student who has completed at least two quarters at UCLA and is involved in student organizations, programs, projects, or community service.

General Motors Scholarship. For aerospace, mechanical, or electrical engineering majors.

Audrey and James Gilstrap Scholarship. For engineering students

W. Brandt Goldsworthy Scholarship. For students studying composite materials in the Department of Materials Science and Engineering

Haller Scholarship. Field of electrical engineering; to provide significant assistance, primarily for students 25 years old or over

William J. Knapp Scholarship in Ceramics. For a junior or senior in materials engineering for achievement in studies related to ceramics

Michael J. Kuhlman Memorial Scholarship. For a junior or senior in the electrical engineering field

Paul H. Lane Perpetual Engineering Scholarship. For juniors or seniors (U.S. citizens or permanent residents) in the field of civil (nontransportation), electrical (power option), or mechanical (nonaerospace) engineering; sponsored by the Los Angeles City Department of Water and Power

Lear Siegler Scholarship. For a junior or senior (must be U.S. citizen) selected by priority from aerospace engineering, electrical engineering, mechanical engineering (CAD/CAM emphasis), computer science and engineering

Maxim Scholarship. For a student from northern California in electrical engineering; four-year award

Joseph W. McCutchan Memorial Scholarship Fund. Field of engineering

Richard B. Nelson Memorial Scholarship Fund. For civil engineering students with an interest in structures

Rhone-Poulenc Contribution to Excellence Scholarship. For a junior or senior in the field of chemical engineering

Dick and Pat Stern Scholarship. For an engineering student with high academic achievement

Texaco Scholarship. For chemical, civil, and mechanical engineering majors with interest in the petroleum industry

For more scholarship information, see http://seasoasa.ucla.edu/fee.html

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 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.

Detailed information on other grants for students with demonstrated need is available from the Financial Aid Office, A129J Murphy Hall, (310) 206-0400.

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. Most community service positions are located off campus.

Students must be enrolled at least half-time (6 units for undergraduates, 4 for graduate students) and not be appointed at more than 50 percent time while employed at UCLA. Students not carrying the required units or who exceed 50 percent time employment are subject to Social Security or Medicare taxation.

Graduate Students

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

Merit-Based Support

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

1. Fellowships from University, private, or corporate funds (465 positions).
2. Employment as a teaching assistant (about 473 positions).
3. Employment as a graduate student researcher (about 1513 positions).

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

Teaching assistantships are awarded to students on the basis of scholarship and promise as teachers. Appointees serve under the supervision of regular faculty members. Half-time salaries (50 percent time) range from $14,573* to $17,086*, depending on experience.

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. Half-time salaries (49 percent time) range from $14,628† to $28,668†, depending on experience. 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.

*Nine-month 2004-05 salaries
†Eleven-month 2004-05 salaries

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2005-06 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 2005 for information on 2006-07 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:

AT&T Fellowships. Supports doctoral study in electrical engineering; must be U.S. citizen or permanent resident; optional summer research at AT&T

Atlantic Richfield Company (ARCO) Fellowship. Department of Chemical and Biomolecular Engineering; supports study in chemical engineering

William and Mary Beedle Fellowship. Department of Chemical Biomolecular Engineering; supports study in chemical engineering

John J. and Clara C. Boelter Fellowship. Supports study in engineering

Leon and Alyne Camp Fellowship. Department of Mechanical and Aerospace Engineering; supports study in engineering; must be U.S. citizen

Deutsch Company Fellowship. Supports engineering research on problems that aid “small business” in Southern California

GTE Fellowship. Departments of Computer Science and Electrical Engineering; supports study in computer science and electrical engineering

IBM Doctoral Fellowship. Supports doctoral study in computer science

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

T.H. Lin Graduate Fellowship. Department of Civil and Environmental Engineering; supports study in the area of structures

Microelectronics Innovation and Computer Research Opportunities (MICRO). Supports students in electrical engineering, computer science, and materials science and engineering with interest in microelectronics who intend to remain in California after graduation; must be U.S. citizen or permanent resident

Microsoft Fellowship. Supports doctoral study in computer science

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

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

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

Semiconductor Research Corporation Fellowship. Department of Electrical Engineering; supports doctoral students in microelectronics; must be U.S. citizen

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

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

Many other companies in the area also make arrangements for their employees to work part-time and to study at UCLA for advanced degrees in engineering or computer science.

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 students in precollege, undergraduate, and graduate science, engineering, mathematics, and technology curricula.

Precollege Outreach Programs

Science and Mathematics Achievement and Research Training for Students (SMARTS). A six-week commuter and residential summer program, SMARTS provides a diverse group of 50 to100 ninth to twelfth graders with rigorous inquiry-based engineering, mathematics, and science enrichment. Tenth and eleventh graders 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. Students continue their involvement during the school year by participating in the Saturday Academy Series in Fall and Spring Quarters.

MESA Schools Program (MSP). Through CEED, HSSEAS partners with middle and high school principals to implement MSP services, which focus on outreach and student development in engineering, mathematics, science, and technology. At individual school sites, four mathematics and science teachers serve as MSP advisers and coordinate the activities and instruction for 1,400 students. Advisers work as a team to deliver services that include SAT preparation. MSP prepares students for regional engineering and science competitions and provides an individual academic planning program, academic excellence workshops, CEED undergraduate mentors, field trips, and exposure to high-tech careers. The MSP goal is to increase the numbers of urban and educationally underserved students who are competitively eligible for UC admission, particularly in engineering and computer science.

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

Undergraduate Programs

CEED currently supports some 250 underrepresented and disadvantaged engineering students. Components of the undergraduate program include

CEED Summer Bridge. A two-week intensive residential summer program, CEED Summer Bridge provides advanced preparation and exposure for Fall Quarter classes in mathematics, chemistry, and computer science.

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

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.

Students join together to solve a math problem at an academic excellence workshop.

Bridge Review for Enhancing Engineering Students (BREES). Sponsored by Hewlett Packard. 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.

The UCLA/Hewlett-Packard Computer Science/Engineering Retention Project, coordinated by CEED, is a pilot effort to improve student retention through the redesign of and integration of technology into core engineering courses. In particular, the effort utilized a HP-donated wireless mobile classroom (a wireless laptop cart) to facilitate instruction and interaction in special sessions of EE 10 and EE 115A. A joint effort between the Electrical Engineering Department and UCLA Center for the Study of Evaluation designed and assessed these special sessions to improve instructor feedback and engage students in a significantly enhanced instructional environment. Overall, the pilot effort has proved promising, and continued collaboration is in place to fully integrate the redesign into core engineering courses.

Academic Advising and Counseling. CEED counselors assist in the selection of course combinations, professors, and course loads and meet 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 three-room complex with a study area open 24 hours a day, the Student Study Center also houses academic workshop rooms and a computer room and is used for tutoring, presentations, and engineering student organizations. The center has an electronic message board for campus, student organization, and CEED activities and numerous bulletin boards for scholarships and employment opportunities.

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 UCLA's 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 80 percent of the 700,000 K-12 students in the Los Angeles Unified School District are African-American and Latino, yet a miniscule 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.

Graduate Programs

OMEGA. The last letter in the Greek alphabet, OMEGA symbolizes the highest level of educational achievement. The organization is a partnership with engineering faculty and CEED to increase the number of UCLA CEED and other engineering undergraduates who are interested in graduate study.

The OMEGA Research Program provides stipends for CEED undergraduates to conduct engineering research with engineering faculty mentors.

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's 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 fourteenth 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 publication of a résumé book, cosponsored by AISES and SOLES, and their industry sponsored annual Awards and Installation Banquet. Through the various activities sponsored by NSBE, students develop leadership and interpersonal skills while enjoying the college experience. See http://www.seas.ucla.edu/nsbe/.

Society of Latino Engineers and Scientists

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

SOLES also strives to familiarize the UCLA community with the richness and diversity of the Latino culture and the scientific accomplishments of Latinos. SOLES organizes cultural events such as Latinos in Science, Cinco de Mayo, and cosponsors the Women in Science and Engineering (WISE) Day with AISES, NSBE, and SWE. 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.seas.ucla.edu/soles/.

Women in Engineering

Women make up about 23 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 "males only" field. Women engineers are in great demand in all fields of engineering.

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/academics/organization.html.

EGSA	Engineering Graduate Students Association
ESUC	Engineering Society, University of California. Umbrella organization for all the engineering and technical societies at UCLA
ACM	Association for Computing Machinery
AIAA	American Institute of Aeronautics and Astronautics
AIChE	American Institute of Chemical Engineers
AISES	American Indian Science and Engineering Society
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
BMES	Biomedical Engineering Society
Chi Epsilon	Civil Engineering Honor Society
Eta Kappa Nu	Electrical engineering honor society
EWB	Engineers Without Borders
IEEE	Institute of Electrical and Electronic Engineers
MRS	Materials Research Society
NSBE	National Society of Black Engineers
Phi Sigma Rho	Engineering social sorority
PIE	Pilipinos in Engineering
SAE	Society of Automotive Engineers
SOLES	Society of Latino Engineers and Scientists
SWE	Society of Women Engineers
Tau Beta Pi	Engineering honor society
Triangle	Social fraternity of engineers, architects, and scientists

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.

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, and furtherance of the undergraduate engineering program, with emphasis on extracurricular activities.

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. Engineering students are advised to purchase it from the UCLA Store.

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

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), disability, age, medical condition (cancer-related), ancestry, marital status, citizenship, sexual orientation, or status as a Vietnam-era veteran or special disabled veteran. 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. Speech- and hearing-impaired persons may call TTY (310) 206-6083.

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 Karen Henderson-Winge, Coordinator of ADA and 504 Compliance, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 825-7906, TTY (310) 206-3349; http://www.saonet.ucla.edu/ada.htm.

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

Every member of the University community should be aware that the University will not tolerate sexual harassment and that such behavior is prohibited both by law and by University policy. See http://www.sexualharassment.ucla.edu.

Definitions

Unwelcome sexual advances, requests for sexual favors, and other verbal, nonverbal, or physical conduct of a sexual nature constitute sexual harassment when

a. A student who is also an employee of the University makes submission to such conduct, either explicitly or implicitly, a term or condition of instruction, employment, or participation in other University activity over which the student has control by virtue of his or her University employment; or

b. A student who is also an employee of the University makes submission to or rejection of such conduct a basis for evaluation in making academic or personnel decisions affecting an individual, when the student has control over such decisions by virtue of his or her University employment; or

c. Such conduct by any student has the purpose or effect of creating a hostile and intimidating environment sufficiently severe or pervasive to substantially impair a reasonable person's participation in University programs or activities, or use of University facilities

In determining whether the alleged conduct constitutes sexual harassment, consideration shall be given to the record of the incident as a whole and to the totality of the circumstances, including the location of the incident and the context in which the alleged incidents occurred. In general, a charge of harassing conduct can be addressed under the *UCLA Code* only when the University can reasonably be expected to have some degree of control over the alleged harasser and over the environment in which the conduct occurred.

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 alleged offender's supervisor and/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. Center for Student Programming, Associate Director, 105 Kerckhoff Hall, (310) 825-7041

3. Center for Women and Men, Director, B44 Student Activities Center, (310) 825-3945
4. Chancellor's Office, Sexual Harassment Coordinator, 2241 Murphy Hall, (310) 206-3417
5. David Geffen School of Medicine, Senior Associate Dean of Student Affairs/Graduate Medical Education, 12-139 Center for the Health Sciences, (310) 825-6774; Dean's Office, Special Projects Director, 12-138 Center for the Health Sciences, (310) 794-1958
6. Graduate Division, Office Manager, 1237 Murphy Hall, (310) 206-3269
7. Healthcare Human Resources, Employee Relations Manager, 400 UCLA Wilshire Center, (310) 794-0500
8. Lesbian Gay Bisexual Transgender Campus Resource Center, Director, B36 Student Activities Center, (310) 206-3628
9. Neuropsychiatric Hospital, Administration/Human Resources Associate Director, B7-370 NPI&H, (310) 206-5258
10. Office of the Dean of Students, Assistant Dean of Students, 1206 Murphy Hall, (310) 825-3871
11. Office of International Students and Scholars, 106 Bradley Hall, (310) 825-1681
12. Office of Ombuds Services, 105 Strathmore Building, (310) 825-7627
13. Office of Residential Life, Judicial Coordinator, Residential Life Building, 370 De Neve Drive, (310) 825-3401
14. Santa Monica-UCLA Medical Center, Healthcare Human Resources Director, 1250 16th Street, Santa Monica 90404, (310) 319-4351
15. School of Dentistry, Assistant Dean, Student Affairs, 10-135A Dentistry, (310) 825-2615
16. Staff Affirmative Action Office, Staff Affirmative Action Officer, 1050 UCLA Wilshire Center, (310) 794-0691
17. Student Legal Services, Director, 70 Dodd Hall, (310) 825-9894
18. Student Psychological Services, Director, Wooden Center West, (310) 825-0768
19. UCLA Extension, Human Resources Director, 629 UNEX Building, (310) 825-4287; Student Services Director, 214 UNEX Building, (310) 825-2656

Other Forms of Harassment

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

For example, harassing expression which is accompanied by physical abuse, threats of violence, or conduct that threatens the health or safety of any person on University property or in connection with official University functions may subject an offending student to University discipline under the provisions of Section 102.08 of the *Policies*.

Similarly, harassing conduct, including symbolic expression, which also involves conduct resulting in damage to or destruction of any property of the University or property of others while on University premises may subject a student violator to University discipline under the provisions of Section 102.04 of the *Policies*.

Further, under specific circumstances described in 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. Center for Women and Men, B44 Student Activities Center, (310) 825-3945, http://www.thecenter.ucla.edu
2. Office of Fraternity and Sorority Relations, 105 Kerckhoff Hall, (310) 825-6322, http://www.greeklife.ucla.edu
3. Office of International Students and Scholars, 106 Bradley Hall, (310) 825-1681, http://www.intl.ucla.edu
4. Office of Ombuds Services, 105 Strathmore Building, (310) 825-7627, http://www.saonet.ucla.edu/ombuds/
5. Office of Residential Life, Residential Life Building, 370 De Neve Drive, (310) 825-3401, http://www.orl.ucla.edu
6. Student Psychological Services, Wooden Center West, (310) 825-0768, http://www.sps.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).

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.

Admission

Applicants to HSSEAS must satisfy the general admission requirements of the University. See the Office of Admissions and Relations with Schools (UARS) website at http://www.admissions.ucla.edu for details. Applicants must select a major within the school when applying for admission. In the selection process many elements are considered, including grades, test scores, and academic preparation.

Students 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.

Effective for students entering the University of California as freshman applicants in Fall Quarter 2006: each applicant 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 ACT Writing Test 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 science, 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 2005 fulfills HSSEAS requirements as indicated on the AP chart.

Students who have completed 36 quarter units after high school graduation at the time of the examination receive no AP Test credit.

Admission as a Transfer Student

Admission as a junior-level transfer student is competitive. The University requires applicants to have completed a minimum of 60 transferable semester units (90 quarter units) and two transferable English courses prior to enrolling at UCLA. In addition, to be considered all applicants to HSSEAS majors must have at least a 3.2 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

Henry Samueli School of Engineering and Applied Science
Advanced Placement Credit

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.

AP Test	Score	UCLA Lower Division Units and Course Equivalents	Credit Allowed for University and GE Requirements
Art History	3, 4, or 5	8 excess units	No application
Art, Studio		8 units maximum for all tests	
Drawing Portfolio	3, 4, or 5	8 excess units	No application
Two-Dimensional Design Portfolio	3, 4, or 5	8 excess units	No application
Three-Dimensional Design Portfolio	3, 4, or 5	8 excess units	No application
Biology	3, 4, or 5	8 excess units	No application
Chemistry	3	8 excess units	No application
	4 or 5	4 units (may petition for Chemistry 20A) plus 4 excess units	No application
Computer Science		4 units maximum for both tests	
Computer Science (A Test)	3, 4, or 5	2 excess units	No application
Computer Science (AB Test)	3, 4, or 5	4 excess units	No application
Economics			
Macroeconomics	3	4 excess units	No application
	4	Economics 2 (4 excess units)	No application
	5	Economics 2 (4 units)	4 units toward social analysis GE
Microeconomics	3	4 excess units	No application
	4	Economics 1 (4 excess units)	No application
	5	Economics 1 (4 units)	4 units toward social analysis GE
English		8 units maximum for both tests	
Language and Composition	3	8 excess units	Satisfies Entry-Level Writing Requirement
	4 or 5	English Composition 3 (5 units) plus 3 excess units	Satisfies Entry-Level Writing Requirement
Literature and Composition	3	8 excess units	Satisfies Entry-Level Writing Requirement
	4 or 5	English Composition 3 (5 units) plus 3 excess units	Satisfies Entry-Level Writing Requirement
Environmental Science	3, 4, or 5	4 excess units	No application
Geography, Human	3, 4, or 5	4 excess units	No application
Government and Politics			
Comparative	3, 4, or 5	4 excess units	No application
United States	3, 4, or 5	4 excess units	Satisfies American History and Institutions Requirement
History			
European	3	4 excess units	No application
	4 or 5	8 excess units	No application
United States	3, 4, or 5	8 excess units	Satisfies American History and Institutions Requirement
World	3, 4, or 5	8 excess units	No application

Languages and Literatures			
French Language	3	French 4 (4 units) plus 4 excess units	No application
	4	French 5 (4 units) plus 4 excess units	No application
	5	French 6 (4 units) plus 4 excess units	4 units toward philosophical and linguistic analysis GE
French Literature	3 or 4	8 excess units	No application
	5	4 GE units plus 4 excess units	4 units toward literary and cultural analysis GE
German Language	3	German 3 (4 units) plus 4 excess units	No application
	4	German 4 (4 units) plus 4 excess units	No application
	5	German 5 (4 units) plus 4 excess units	4 units toward philosophical and linguistic analysis GE
Latin		8 units maximum for both tests	
Latin Literature	3	Latin 1 (4 units)	No application
	4	Latin 3 (4 units)	No application
	5	Latin 3 (4 units)	4 units toward literary and cultural analysis GE
Vergil	3	Latin 1 (4 units)	No application
	4	Latin 3 (4 units)	No application
	5	Latin 3 (4 units)	4 units toward literary and cultural analysis GE
Spanish Language	3	Spanish 4 (4 units) plus 4 excess units	No application
	4	Spanish 5 (4 units) plus 4 excess units	No application
	5	Spanish 6 (4 units) plus 4 excess units	4 units toward philosophical and linguistic analysis GE
Spanish Literature	3 or 4	8 excess units	No application
	5	4 GE units plus 4 excess units	4 units toward literary and cultural analysis GE
Mathematics		8 units maximum for both tests	
Mathematics (AB Test: Calculus)	3	4 excess units	No application
	4	4 excess units	No application
	5	4 units	May be applied toward Mathematics 31A
Mathematics (BC Test: Calculus)	3	8 excess units	No application
	4	4 excess units plus 4 units	4 units may be applied toward Mathematics 31A
	5	8 units	Mathematics 31A plus 4 units that may be applied toward Mathematics 31B
Music Theory	3, 4, or 5	8 excess units	No application
Physics		8 units maximum for all tests	
Physics (B Test)	3, 4, or 5	8 excess units	No application
Physics (C Test: Mechanics)	3	4 excess units	No application
	4 or 5	4 units (may petition for Physics 1A)	No application
Physics (C Test: Electricity and Magnetism)	3, 4, or 5	4 excess units	No application
Psychology	3	4 excess units	No application
	4	Psychology 10 (4 excess units)	No application
	5	Psychology 10 (4 units)	4 units toward social analysis GE
Statistics	3, 4, or 5	4 excess units	No application

and Engineering major requires only one term of chemistry; the Computer Science major does not require chemistry, but one term of chemistry may be applied as a life sciences course

4. Computer programming, including either Fortran, Pascal, C programming, or C++. Applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors should take C++.
5. Biology, including one year of biology only for applicants to the Bioengineering major
6. English composition courses, including one course equivalent to UCLA's English Composition 3 and a second UC-transferable English composition course

Transfer applicants may complete courses in addition to those above that satisfy degree requirements. Engineering and computer science courses appropriate for each major may be found at http://www.assist.org.

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 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. See Degree Requirements in the Undergraduate Study section for details. 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 four requirements that must be satisfied for the award of the degree: unit, scholarship, academic residence, and general education.

Unit Requirement

The minimum units allowed for HSSEAS students is between 181 and 205, 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.

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.

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

Students may take one HSSEAS 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.

Requirements for Students Who Entered Fall Quarter 2005 and Thereafter

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-quarter writing requirement–W riting I and Writing II. Two courses in English composition are required for graduation. Both courses must be taken for a letter grade, and students must receive grades of C or better (C— grades are not acceptable).

Writing I

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

The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement Tests in English or a combination of a score of 720 or better on the SAT II Subject Test in Writing and superior performance on the English Composition 3 Proficiency Examination.

Students whose native language is not English may satisfy the Writing I requirement by completing English as a Second Language 36 with a grade of C or better (C— or a Passed grade is not acceptable). Admission into the course is determined by completion of English as a Second Language 35 with a passing grade or proficiency demonstrated on the English as a Second Language Placement Examination (ESLPE).

Writing II

The Writing II requirement is satisfied by selecting one approved writing (W) course from the HSSEAS GE foundations course list. Writing II course lists are also available in the Office of Academic and Student Affairs. The course must be completed with a grade of C or better (C— or a Passed grade is not acceptable).

Ethics Requirement

HSSEAS majors are required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185 for a letter grade.

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. One of the five courses must be a GE-approved Writing II (W) course.

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 students with the perspectives and intellectual skills necessary to comprehend and think critically about our situation in the world as human beings. In particular, the courses provide students with 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 supplemented by the following: Biomedical Engineering CM145/ Chemical Engineering CM145, Chemistry and Biochemistry 153A, and Civil and Environmental Engineering M166/Environmental Health Sciences M166:

Life Sciences

This requirement is automatically satisfied for Bioengineering majors, the bioengineering and biomedical options of the Chemical Engineering major, and the biomedical option of the Electrical Engineering major. The requirement may be satisfied for the chemical, environmental, and semiconductor options of the Chemical Engineering major and 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/GE-ENGRNew05-06.pdf.

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

Course requirements for the B.S. degrees include the following categories, depending on curriculum selected:

1. Fourteen to 21 engineering major field courses (56 to 84 units), depending on curriculum followed
2. One to 10 engineering core courses (4 to 40 units), depending on curriculum selected

3. Mathematics courses, ranging from 4 to 12 upper division units; see curricula in individual departments

Lists of courses approved to satisfy specific curricular requirements are available from the Office of Academic and Student Affairs.

Policies and Regulations

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

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

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

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

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.

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 sophomore year or earlier.

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

Curricula Planning Procedure

1. Students normally follow the curriculum in effect when they enter the school. California community college transfers 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.
2. All HSSEAS undergraduates may use the computerized HSSEAS Academic Program Planner (APP), an interactive self-advising system that informs users if their academic programs meet the requirements for graduation. Students beginning upper division coursework in the major are required to submit an Academic Program Proposal to the Office of Academic and Student Affairs for approval by the associate dean.

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

Latin Honors

Students who have achieved scholastic distinction may be awarded the bachelor's degree with honors. Students eligible for 2005-06 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 3.834 or better) for *summa cum laude,* the next five percent (GPA of 3.728 or better) for *magna cum laude,* and the next 10 percent (GPA of 3.575 or better) for *cum laude.*

Based on grades achieved in upper division courses, engineering students must have a 3.834 grade-point average for *summa cum laude,* a 3.728 for *magna cum laude,* and a 3.575 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 Engineering degree, and to the Engineer degree. The school is divided into seven departments that encompass the major engineering disciplines: aerospace engineering, bioengineering, chemical engineering, civil engineering, computer science, electrical engineering, manufacturing engineering, materials science and engineering, and mechanical engineering. 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 opt 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 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) 825-1704.

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

Bioacoustics, speech, and hearing

Biocybernetics

Biomechanics, biomaterials, and tissue engineering

Biomedical instrumentation

Biomedical signal and image processing and bioinformatics

Medical imaging informatics

Molecular and cellular bioengineering

Neuroengineering

Chemical 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 networks

Computer science theory

Computer system architecture

Information and data management

Software systems

Electrical Engineering Department

Applied mathematics (established minor field only)

Communications and telecommunications

Control systems

Electromagnetics

Embedded computing systems

Engineering optimization/operations research

Integrated circuits and systems

Microelectromechanical systems/nanotechnology (MEMS/nano)

Photonics and optoelectronics

Plasma electronics

Signal processing

Solid-state electronics

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 which 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.*

To submit a graduate application, see http://www.seasoasa.ucla.edu/adm_grad.html. 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
7523 Boelter Hall
Box 951600
Los Angeles, CA 90095-1600

(310) 794-5945
fax: (310) 794-5956
e-mail: bioeng@ea.ucla.edu
http://www.bioeng.ucla.edu

Carlo D. Montemagno, Ph.D., *Chair*

Professors

Denise Aberle, M.D.
Timothy J. Deming, Ph.D.
Warren S. Grundfest, M.D., FACS
Hooshang Kangarloo, M.D.
Carlo D. Montemagno, Ph.D. *(Roy and Carol Doumani Professor of Biomedical Engineering)*

Assistant 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

Alfred Mann, M.S.

Adjunct Assistant Professor

Alex Bui, Ph.D.

Scope

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.

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 bioengineering students prepare solutions of proteins to be tested in cell-level experiments.

Bioengineering B.S.

The Major

Course requirements are as follows (198 minimum units required):

1. Bioengineering 10, 100, 110, 120, 165, 176, 180, 180L, 181, 181L, 182A, 182B, 182C; Biomedical Engineering M186B; Chemical Engineering 101A, M105A; Chemistry and Biochemistry 110A, 153A, 156; Electrical Engineering 102 or Mathematics 115A; Molecular, Cell, and Developmental Biology M140
2. Life Sciences 2 (satisfies HSSEAS GE life sciences requirement), 3, 4
3. Two elective courses from Biomedical Engineering C101, CM102, CM103, CM145, M150, M150L, C170, C171, CM180, C181, C185, CM186L
4. Bioengineering 1, 1L, 2, 2L, 3, 3L (Physics 1A, 1B, 1C or Electrical Engineering 1, 4AL, and 4BL may be substituted for courses 1, 1L, 2, 2L, and 3); Chemistry and Biochemistry 14A, 14B, 14BL, 14C, 14CL, 14D (Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, and 30B may be substituted for the 14 series); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 20
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Graduate Study

New graduate programs, leading to M.S. and Ph.D. degrees in Bioengineering, are expected to be in place by Fall Quarter 2006. Program requirements will be updated online at http://www.bioeng.ucla.edu, pending final approval.

Faculty Areas of Thesis Guidance

Professors

Denis 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, supramolecular materials, organometallic catalysis, biomimetic materials, polypeptides

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

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

Carlo D. Montemagno, Ph.D. (Notre Dame, 1995)
Nanotechnology and nanofabrication, biotechnology, BioNEMS, BioMEMS

Assistant 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 analyses of cellular processes, molecular modeling, quantitative cell biology

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

Benjamin M. Wu, D.D.S. (U. Pacific, 1987), Ph.D. (MIT, 1997)
Biomaterials, cell-material interactions, materials processing, tissue engineering, prosthetic and regenerative dentistry

Adjunct Assistant Professor

Alex Bui, Ph.D. (UCLA, 2000)
Medical imaging informatics: probablistic data modeling, visualization of medical information, distributed information architectures for biomedical research

Lower Division Courses

1. Introduction to Biophysics I. (4) 1. Physics for Bioengineers I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Corequisite: Mathematics 31A. Introduction to physics and biophysics. Basic topics in physics from biological perspective and discussion of physical processes associated with biological phenomena. Topics include statics, dynamics, work and energy, oscillations, hydrostatics, biological motion in fluids, waves, sounds, and physics of hearing. Letter grading. Mr. Schmidt (F)

1L. Physics for Bioengineers Laboratory I. (3) (Formerly numbered 4L.) Lecture, one hour; laboratory, four hours; outside study, four hours. Corequisite: course 1 or Physics 1A. Introductory experimental physics laboratory course that explores basic physical concepts from biological perspective. Topics include basic measurement and analysis, static forces and torques, dynamic motion with damping, simple harmonic motion, fluid flow through free and constrained geometries, scale-dependent motion in fluids and Reynolds numbers, surface tension. Letter grading. Mr. Schmidt (F)

2. Physics for Bioengineers II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 1 or Physics 1A, Mathematics 31A. Corequisite: Mathematics 31B. Introduction to physics and biophysics. Basic topics in physics from biological perspective and discussion of physical processes associated with biological phenomena. Topics include kinetic theory of gases, statistical mechanics, diffusion, thermodynamics, physics of biopolymers and biomembranes, electric and magnetic fields, electricity in aqueous media. Letter grading. Mr. Schmidt (W)

2L. Physics for Bioengineers Laboratory II. (3) (Formerly numbered 5L.) Lecture, one hour; laboratory, four hours; outside study, four hours. Requisite: course 1L or Physics 4AL. Corequisite: course 2 or Physics 1B. Continuation of course 1L. Second introductory experimental physics laboratory course that explores basic physical concepts from biological perspective. Topics include behavior of ideal gases, thermal transport, electric fields, electricity in aqueous media, simple electric circuits of resistors, inductors, and capacitors, electric circuit analogs in biological systems, optics of microscope, physics of light gun eration and absorption, fluorescence, laser in biology. Letter grading. Mr. Schmidt (W)

3. Physics for Bioengineers III. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 2 or Physics 1B, Mathematics 31B. Corequisite: Mathematics 32A. Introduction to physics and biophysics. Basic topics in physics from biological perspective and discussion of physical processes associated with biological phenomena. Topics include DC and AC circuits, ion channels, biological circuits, Maxwell equations, electromagnetic waves, interference and diffraction, geometric optics, optics of eye and compound microscope, quantum physics, NMR and MRI, fluorescence. Letter grading. Mr. Schmidt (Sp)

3L. Physics for Bioengineers Laboratory III. (3) Lecture, one hour; laboratory, four hours; outside study, four hours. Requisites: course 2 or Physics 1B, Mathematics 31B. Corequisites: course 3 or Electrical Engineering 1 or Physics 1C, Mathematics 32A. Continuation of course 2L. Third introductory experimental physics laboratory course that explores basic physical concepts from biological perspective. Topics include resistors, capacitors, and inductors, passive DC and AC circuits, active circuits, electric circuit analogs in biological systems, optics of lens and eye, compound microscope, physics of light generation and absorption, fluorescence. Letter grading. Mr. Schmidt (Sp)

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

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

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

Upper Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C (may be taken concurrently), Chemistry 14C or 30A, Mathematics 32B (may be taken concurrently). Fundamental basis for analysis and design of biological and biomedical devices and systems. Material, energy, charge, and force balances. Introduction to network analysis. Letter grading. Mr. Kamei (F)

110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemical Engineering 101A, M105A (or Mechanical and Aerospace Engineering M105A), Chemistry 153A, Life Sciences 3, Mathematics 33B. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body, extracorporeal devices, tissue engineering systems, and bioartificial organs. Introduction to pharmacokinetic analysis. Letter grading. Mr. Kamei (W)

120. Biomedical Transducers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 14C or 30A, Mathematics 32B. Principles of transduction, design characteristics for different measurements, reliability and performance characteristics, and data processing and recording. Emphasis on silicon-based microfabricated and nanofabricated sensors. Novel materials, biocompatibility, biostability. Safety of electronic interfaces. Actuator design and interfacing control. Letter grading. Mr. Grundfest (Sp)

165. Bioethics and Regulatory Policies in Bioengineering. (2) Lecture, two hours; outside study, four hours. Requisite: course 180. Increasing pace of biotechnological development requires intensive preparation for young scientists (i.e., graduate students, postdoctoral research fellows, and junior faculty) on issues in bioethics and regulatory policy. Examination of role of scientists in participating in, supporting, or opposing establishment of regulatory frameworks, relationship between scientists and socioeconomic movements by general public and individuals, and discussion of role of scientists in public arena, academic institutions, media, and industry. May be appropriate for students who already have some knowledge and/or experience in molecular biology, genetics, or biotechnology. Letter grading. Mr. Wu (Sp)

176. Principles of Biocompatibility. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 153A, Mathematics 33B. Biocompatibility at systemic, tissue, cellular, and molecular levels. Biomechanical compatibility, stress/strain constitutive equations, cellular and molecular response to mechanical signals, biochemical and cellular compatibility, immune response. Letter grading. Mr. Wu (F)

180. System Integration in Biology, Engineering, and Medicine I. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: courses 3L, 100, 110, 120, Life Sciences 3. 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 (F)

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 (F)

181. System Integration in Biology, Engineering, and Medicine II. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: 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 181. 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. (2-2-2) 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 biorobots or most stable UCLA logo or most selective and efficient biomarker sensors, etc.). Letter grading. **182A.** Lecture, two hours; outside study, four hours. Requisites: courses 3L, 120. Development, writing, and oral defense of student design proposals. **182B.** Lecture, two hours; laboratory, three hours; outside study, one hour. Requisite: course 182A. Exploration of different experimental and computational methods. Ordering of specific materials and software that are relevant to student projects. **182C.** Lecture, two hours; laboratory, three hours; outside study, one hour. Requisite: course 182B. Construction of student designs, project updates, presentation of final projects in written and oral format, and team competition. Mr. Deming (F,W,Sp)

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

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

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. (F,W,Sp)

Biomedical Engineering

Interdepartmental Program

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Carlo D. Montemagno, Ph.D., *Chair*

Faculty Advisory Committee

Timothy J. Deming, Ph.D. *(Bioengineering)*
Bruce S. Dunn, Ph.D. *(Materials Science and Engineering)*
Chih-Ming Ho, Ph.D. *(Mechanical and Aerospace Engineering)*
Hooshang Kangarloo, M.D. *(Pediatrics, Radiological Sciences)*
John D. Mackenzie, Ph.D. *(Materials Science and Engineering)*
Carlo D. Montemagno, Ph.D. *(Bioengineering)*
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. *(Dentistry)*
James N. Weiss, M.D. *(Cardiology)*

Professors

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Peng-Shen Chen, Ph.D., *in Residence (Medicine)*
Yong Chen, Ph.D. *(Mechanical and Aerospace Engineering)*
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Hooshang Kangarloo, M.D. *(Pediatrics, Radiological Sciences)*
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Chang-Jin Kim, Ph.D. *(Mechanical and Aerospace Engineering)*
J. John Kim, Ph.D. *(Mechanical and Aerospace Engineering)*
Jess F. Kraus, Ph.D., M.P.H. *(Epidemiology)*
Elliot M. Landaw, M.D., Ph.D. *(Biomathematics)*
Andrew F. Leuchter, M.D. *(Psychiatry and Biobehavioral Sciences)*
James C. Liao, Ph.D. *(Chemical and Biomolecular Engineering)*
Jia-Ming Liu, Ph.D. *(Electrical Engineering)*
Ajit K. Mal, Ph.D. *(Mechanical and Aerospace Engineering)*
Keith Markolf, Ph.D. *(Orthopaedic Surgery)*
Edward McCabe, M.D. *(Pediatrics)*
Harry McKellop, Ph.D., *in Residence (Orthopaedic Surgery)*
Istvan Mody, Ph.D. *(Neurology, Physiology)*
Harold G. Monbouquette, Ph.D. *(Chemical and Biomolecular Engineering)*
Carlo D. Montemagno, Ph.D. *(Bioengineering, Mechanical and Aerospace Engineering)*
Sherie L. Morrison, Ph.D. *(Microbiology, Immunology, and Molecular Genetics)*
Peter M. Narins, Ph.D. *(Ecology and Evolutionary Biology, Physiological Science)*
Stanley Nelson, M.D. *(Human Genetics)*
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. *(Dentistry)*
D. Stott Parker, Jr., Ph.D. *(Computer Science)*
Yahya Rahmat-Samii, Ph.D. *(Electrical Engineering)*
Shlomo Raz, M.D. *(Urology)*
Vwani Roychowdhury, Ph.D. *(Electrical Engineering)*
Michael Sofroniew, M.D., Ph.D. *(Neurobiology)*
James G. Tidball, Ph.D. *(Physiological Science)*
Arthur Toga, Ph.D. *(Neurology)*
James N. Weiss, M.D. *(Cardiology)*

Owen N. Witte, Ph.D. *(Microbiology and Molecular Genetics)*
Ming C. Wu, Ph.D. *(Electrical Engineering)*
Jenn-Ming Yang, Ph.D. *(Materials Science and Engineering)*
Kung Yao, Ph.D. *(Electrical Engineering)*
Carlo Zaniolo, Ph.D. *(Computer Science)*

Professors Emeriti

Thelma Estrin, Ph.D. *(Computer Science)*
Allen Klinger, Ph.D. *(Computer Science)*
John D. Mackenzie, Ph.D. *(Materials Science and Engineering)*
Jacques J. Vidal, Ph.D. *(Computer Science)*

Associate Professors

Marvin Bergsneider, M.D. *(Neurosurgery)*
Susan Y. Bookheimer, Ph.D. *(Psychiatry and Biobehavioral Sciences)*
Samson Chow, Ph.D. *(Molecular and Medical Pharmacology*
Jack W. Judy, Ph.D. *(Electrical Engineering)*
Dario Ringach, Ph.D. *(Neurobiology, Psychology)*
Shantanu Sinha, Ph.D. *(Radiological Sciences)*
Desmond Smith, Ph.D. *(Molecular and Medical Pharmacology)*
Igor Spigelman, Ph.D. *(Dentistry)*
Paul M. Thompson, Ph.D., *in Residence (Neurology)*
Peter Tontonoz, M.D., Ph.D. *(Pathology)*
Jeffrey Wang, M.D. *(Orthopaedic Surgery)*
Lily Wu, Ph.D. *(Molecular and Medical Pharmacology, Urology)*

Assistant Professors

Ramin Beygui, M.D. *(Surgery)*
Arion Chattziioannou, Ph.D. *(Molecular and Medical Pharmacology)*
Thomas Chou, Ph.D. *(Biomathematics)*
Ian A. Cook, M.D. *(Psychiatry and Biobehavioral Sciences)*
Katrina Dipple, M.D., Ph.D. *(Human Genetics and Pediatrics)*
James Dunn, M.D., Ph.D. *(Bioengineering, Pediatric Surgery)*
Lee Goodglick, Ph.D. *(Pathology and Laboratory Medicine)*
Susan Harkema, Ph.D. *(Neurology)*
George Huang, D.Sc., D.D.S. *(Dentistry)*
Yongho Ju, Ph.D. *(Mechanical and Aerospace Engineering)*
Daniel T. Kamei, Ph.D. *(Bioengineering)*
Pirouz Kavehpour, Ph.D. *(Mechanical and Aerospace Engineering)*
Irwin Kurland, Ph.D. *(Medicine/Endocrinology)*
Heather Maynard, Ph.D. *(Chemistry and Biochemistry)*
Sheila Nirenberg, Ph.D. *(Neurology)*
Jacob Schmidt, Ph.D. *(Bioengineering)*
Felix Schweitzer, Ph.D. *(Neurobiology)*
Kang Ting, D.M.D, D.M.Sc. *(Dentistry)*
Benjamin Wu, D.D.S., Ph.D. *(Bioengineering, Dentistry, Materials Science and Engineering)*

Adjunct Professors

Guido Germano, Ph.D. *(Radiological Sciences)*
John J. Gilman, Ph.D. *(Materials Science and Engineering)*
Boris Kogan, Ph.D. *(Computer Science)*

Adjunct Associate Professors

Vivek Dixit, Ph.D. *(Medicine)*
Marc Hedrick, M.D. *(Surgery)*
Valeriy I. Nenov, Ph.D. *(Neurosurgery)*
Usha Sinha, Ph.D. *(Radiological Sciences)*
Imke Schroeder, Ph.D. *(Microbiology, Immunology, and Molecular Genetics)*
Ricky Taira, Ph.D. *(Radiological Sciences)*
Daniel J. Valentino, Ph.D. *(Radiological Sciences)*

Adjunct Assistant Professors

Alex Bui, Ph.D. *(Radiological Sciences)*
Robert Close, Ph.D. *(Radiological Sciences)*
Robert Goldberg, M.D., Ph.D. *(Electrical Engineering)*

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 seven 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 departments across campus and well-equipped laboratories for graduate research projects.

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the "Publications" link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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 Biomedical Engineering C201, CM202, CM203, 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 on the written portion of the Ph.D. preliminary examination. Eight of the 12 courses must be graduate (200-level) courses, and students must maintain a grade-point average of B or better in both upper division and graduate courses. Three Biomedical Engineering 299 courses (6 units total) are also required.

Biomedical Engineering Ph.D.

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

Fields of Study

Bioacoustics, Speech, and Hearing

The bioacoustics, speech, and hearing field trains biomedical engineers to apply concepts and methods of engineering and physical and biological sciences to solve problems in speech and hearing. To meet this goal, the program combines a rigorous curriculum in quantitative methods for studying speech and hearing and an exposure to biomedical issues.

Course Requirements

Core Courses (Required). Biomedical Engineering C201, CM202, CM203, M214A, 230.

Electives. Computer Science 276C, Electrical Engineering 214B, Linguistics 204, Neuroscience 274, Physics 114, Physiological Science M173, M290, Psychiatry 298.

Remedial courses are taken as necessary. For students without previous exposure to signal processing, Electrical Engineering 102 and 113 are recommended.

Biocybernetics

Graduate study in biocybernetics is intended for science or engineering students interested in 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 engineering, medicine, and/or the biomedical sciences, or research and development in the biomedical or pharmaceutical industry. At the system and integration level, biocybernetics methodology is quite broadly applicable to a large spectrum of biomedical problems.

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

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

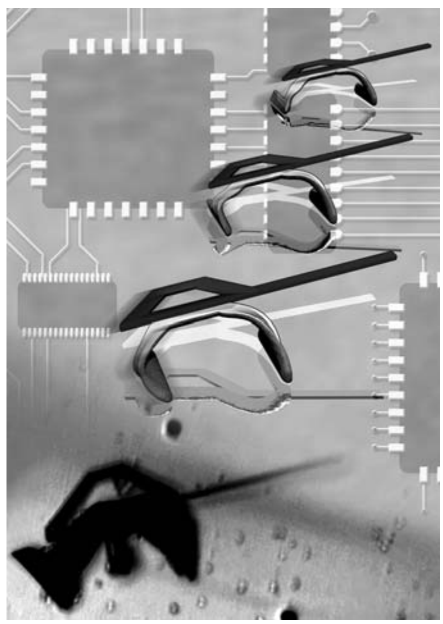
Course Requirements

Biocybernetics 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 M186B, M296A, and one additional graduate-level elective from the additional foundations or electives list.

Core Courses (Required). Biomedical Engineering M186B, C201, CM202, CM203, M296A.

Additional Foundations Courses. Biomedical Engineering M296B, Electrical Engineering 131A, 141, 142, Mathematics 115A, 115B, 151A, 151B, 170A, Statistics 100A, 100B.

Electives. Biomathematics 206, CM208C, 220, M230, Biomedical Engineering M248, CM286L, M296C, M296D, Computer Science 161, 267B, Electrical Engineering 113, 132A, 211A, 211B, M214A, 214B, 232E, M250A, M250B, 260A, 260B, Physics 210B, 231B.



Faculty research combines living tissue with microfabricated structures to create hybrid muscle-MEMS microbots.

Biomechanics, Biomaterials, and Tissue Engineering

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

Course Requirements

Core Courses (Required). Biomedical Engineering C201, CM202, CM203, and two courses from CM240, CM280, C281, 282, C285.

Electives. Chemical Engineering 260, Chemistry and Biochemistry 153A, 153B, 153C, CM153G, CM155, M230B, CM253, CM255, M267A, Civil and Environmental Engineering 235B, Materials Science and Engineering 140, 150, 151, 160, 223, 243A, 244, 245C, 246A, 246D, 250A, 250B, Mechanical and Aerospace Engineering 150A, 156A, 166C, M256A, M256B, M256C, 262, 297, Molecular, Cell, and Developmental Biology CM220, Physiological Science M215, 250A, C250B.

Biomedical Instrumentation

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

Course Requirements

Core Courses (Required). Biomedical Engineering M150L, C201, CM202, CM203, Mechanical and Aerospace Engineering 284.

Electives. Biomedical Engineering CM240, M250B, C270, C271, Electrical Engineering 221A, 221B, 221C, 223, 271, 272, Materials Science and Engineering 200, 201, 246D, Mechanical and Aerospace Engineering 157, 263A, 263D, 280L, 281.

Biomedical Signal and Image Processing and Bioinformatics

The biomedical signal and image processing and bioinformatics 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 and bioinformatics 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, 219, 222, Biostatistics 420, Computer Science 143, 161, Electrical Engineering 211B, 214B.

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

Medical Imaging Informatics

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

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

Course Requirements

Core Courses (Required). Biomedical Engineering 220, 221, 222, 223A, 223B, 223C, 224A, 224B, 226, 227, 228.

Electives. Biomedical Physics 210, 214, Biostatistics 213, M234, 276, Computer Science 217, 240A, 241A, 241B, 244A, 245A, 246, 262A, 262B, M262C, 263A, 263B, 265A, 268, M276A, 276B, Electrical Engineering M202B, 211A, 211B, M217, Information Studies 228, 246, 272, 277, Linguistics 218, 232, Neuroscience CM272.

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, CM202, CM203, and two courses from M215, M225, CM245.

Electives. Biomathematics 220, M270, Biomedical Engineering M186B, M296A, Chemistry and Biochemistry M230B, CM253, CM255, C259A, C259B, 262, M263, C265, M267A, Microbiology, Immunology, and Molecular Genetics C233, CM248, 261, Molecular, Cell, and Developmental Biology CM220, M234.

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, with the active involvement of scientists and technologies from the Jet Propulsion Laboratory (JPL).

The objectives of the neuroengineering field are to enable (1) students with a background in engineering to develop and execute projects that address problems that have a neuroscientific base, including locomotion and pattern generation, central control of movement, and the processing of sensory information; (2) students with a background in biological sciences to develop and execute projects that make use of state-of-the-art technology, including MEMS, signal processing, and photonics. In preparing students to use new technology, the program also introduces them to basic concepts in engineering that are applicable to the study of systems neuroscience, including signal processing, communication, and information theory; and (3) all trainees to develop the capacity for the multidisciplinary teamwork that is necessary for new scientific insights and dramatic technological progress. Courses and research projects are cosponsored by faculty members in both HSSEAS and the Brain Research Institute (BRI).

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

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

Students who are in a field other than neuroengineering and who select neuroengineering as a minor must take Biomedical Engineering M260 and at least one course from two of the following sets of courses: (1) Biomedical Engineering M214A, Electrical Engineering 210A, (2) Biomedical Engineering M250A, M250B, (3) Biomedical Engineering M263, Neuroscience M202.

Required Courses. Biomedical Engineering M260, M263, Neuroscience M202. For MEMS emphasis, required courses are

Biomedical Engineering M150L, M250A, M250B (course M150L is optional if the requisite for course M250A is met). For signal processing and informatics theory emphasis, required courses are Biomedical Engineering M214A and Electrical Engineering 210A, or two other graduate-level engineering courses approved by the adviser and the neuroengineering field chair. In addition, students are required to take a research seminar and problem-based approaches to neuroengineering seminar.

Recommended Electives. During the first and second years, students take at least three courses selected from a menu of new and existing courses.

Biomedical engineering category: Biomedical Engineering C201.

MEMS category: Biomedical Engineering M150L, M250A, M250B, Mechanical and Aerospace Engineering 280L, 284.

Neuroscience category: Neuroscience M201, M263, M273, 274.

Signal processing category: Electrical Engineering 210A, M214A, M217. Remedial courses taken as necessary.

Students without previous exposure to MEMS should take Biomedical Engineering M150L; those without previous exposure to neuroscience should take Physiological Science 111A; those without previous exposure to signal processing should take Electrical Engineering 102 and113. Both courses are offered every quarter.

Seminars (First-Year). Two seminars in problem-based approaches to neuroengineering are required. All first-year students take a new graduate seminar series in Winter and Spring Quarters which is co-taught each quarter by one instructor from HSSEAS and one from the Brain Research Institute. Each seminar introduces students to a single area of neuroengineering 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 neuroengineering. In Fall Quarter, a series called "Meet the Professors" consists of informal talks by UCLA faculty members and collaborative researchers from the surrounding area. The series introduces the faculty to the students and vice versa, and helps faculty in neuroscience and engineering discover opportunities for collaboration that engage students in the neuroengineering program. In Winter and Spring Quarters, seminar speakers are selected from commercial, academic, and government organizations.

Seminars (Second-Year). All second-year students take a seminar course each quarter specifically designed for the neuroengineering 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.

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

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 team 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 in system (organ/tissue) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM202. Letter grading. Mr. Grundfest (F)

CM103. Basic Human Biology for Biomedical Engineers II. (4) (Same as Physiological Science CM103.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, musculoskeletal, endocrine, immune, urinary, reproductive). System-specific modeling/simulations (immune regulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (dialysis, artificial skin, pathogen detectors, ultrasound, birth-control drug delivery). Concurrently scheduled with course CM203. Letter grading. Mr. Grundfest (W)

CM140. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140.) Lecture, four hours; outside study, eight hours. Requisites: Mechanical and Aerospace Engineering 102 (or Civil Engineering 108), 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 generation. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading. Mr. Gupta (W)

C141L. Biomechanics Laboratory. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Requisite: course CM140 or Mechanical and Aerospace Engineering 156A. Hands-on laboratory pertaining to mechanical testing and analysis of long bone specimens. Students, working in pairs, engage in all aspects of procedures. Fundamentals include design and fabrication of signal processing circuitry for use in data acquisition process, including bridge completion circuits, amplifiers, and passive filters; computerized data acquisition using Lab View and A/D input/output (I/O) board; strain measurements on metallic and bone specimens. Finite element analysis of structure under investigation; comparison of experimental, theoretical, and computational results. Concurrently scheduled with course C241L. Letter grading.

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)

M150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Electrical Engineering M150 and Mechanical and Aerospace Engineering M180.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course M150L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Letter grading. Mr. Judy (F)

M150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Electrical Engineering M150L and Mechanical and Aerospace Engineering M180L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Corequisite: course M150. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Letter grading. Mr. Judy (F)

C151. Nanofabrication of Biomedical Systems Using Nonconventional Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course M150L (or Electrical Engineering M150L). Use of nontraditional substrates and materials in fabrication of biomedical nanosystems. Materials and fabrication issues, post-processing integration, compatibility with standard processes, and standard fabrication environment. Packaging concerns. Imaging and diagnostics techniques. Reliability issues. Concurrently scheduled with course C251. Letter grading. Mr. Montemagno (W)

C170. Energy-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Corequisite: course C170L. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C270. Letter grading. Mr. Grundfest (F)

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

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

CM180. Introduction to Biomaterials. (4) (Same as Materials Science CM180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 14. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading. Mr. Wu (W)

C181. Biomaterials-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisite: course CM180. In-depth exploration of host cellular response to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C281. Letter grading. Mr. Wu (Sp)

C185. Introduction to Tissue Engineering. (4) Lecture, three hours; outside study, nine hours. Requisites: course CM102 or 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 C285. Letter grading. Mr. Wu (Sp)

M186A. Introduction to Cybernetics, Biomodeling, and Biomedical Computing. (2) (Formerly numbered M196A.) (Same as Computer Science M186A and Cybernetics M186A.) Lecture, two hours. Requisites: Mathematics 31A, 31B, Program in Computing 10A. Strongly recommended for students with potential interest in biomedical engineering/biocomputing fields or in Cybernetics as a major. Introduction and survey of topics in cybernetics, biomodeling, biocomputing, and related bioengineering disciplines. Lectures presented by faculty currently performing research in one of the areas; some sessions include laboratory tours. P/NP grading. Mr. DiStefano (W)

M186B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered M196B.) (Same as Computer Science M186B, Cybernetics M186B, and Medicine M186B.) Lecture, four hours; discussion, one hour; laboratory, two hours. Requisite: Electrical Engineering 102 or Mathematics 115A. Introduction to dynamic system modeling, compartmental modeling, and computer simulation methods for studying biomedical systems. Basics of numerical simulation algorithms, translating biomodeling goals and data into mathematic models and implementing them for simulation and analysis. Modeling software exploited for class assignments in PC laboratory. Letter grading. Mr. DiStefano

CM186L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Formerly numbered CM196L.) (Same as Computer Science CM186L and Cybernetics M186L.) Lecture, two hours; laboratory, two hours. Requisite: course M186B. Special laboratory techniques and experience in biocybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Comprehensive experiment design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM286L. Letter grading. Mr. DiStefano

188. Special Courses in Biomedical Engineering. (4) (Formerly numbered 198.) Lecture, four hours; outside study, eight hours. Special topics in biomedical engineering for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. 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 team 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 visits to biomedical facilities. Concurrently scheduled with course CM102. Letter grading. Mr. Grundfest (F)

CM203. Basic Human Biology for Biomedical Engineers II. (4) (Same as Physiological Science CM203.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, musculoskeletal, endocrine, immune, urinary, reproductive). System-specific modeling/simulations (immune regulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (dialysis, artificial skin, pathogen detectors, ultrasound, birth-control drug delivery). Concurrently scheduled with course CM103. Letter grading. Mr. Grundfest (W)

M214A. Digital Speech Processing. (4) (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. 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)

M215. Biochemical Reaction Engineering. (4) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemical Engineering 101C and 106, or Chemistry 156. 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; laboratory, two hours; outside study, seven hours. Requisite: Electrical Engineering 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, positron emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, image reconstruction algorithms, system configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. Letter grading.

220. Introduction to Medical Informatics. (2) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to field. 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 architectures, data and process modeling, information extraction and representations, information retrieval and visualization, health services research, telemedicine. Emphasis on current research endeavors and applications. S/U grading. Mr. Kangarloo (F)

221. Human Anatomy and Physiology for Medical Informatics. (4) Lecture, four hours; outside study, eight hours. Corequisite: course 222. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on visualization of anatomy and physiology from imaging perspective. Topics include chest, cardiac, neurology, gastrointestinal/genitourinary, and musculoskeletal systems. Examination of basic imaging physics (magnetic resonance, computed tomography, ultrasound, computed radiography) to provide context for imaging modalities predominantly used to view human anatomy. Geared toward nonphysicians who require more formal understanding of human anatomy/physiology. Letter grading. Mr. El-Saden (F)

222. Clinical Rotation Medical Informatics. (2) Lecture, two hours; laboratory, four hours. Corequisite: course 221. Designed for graduate students. Clinical rotation through medical imaging modalities and clinical environments. Exposure to challenges of medical practice today and clinical usage of imaging, including computed tomography, magnetic resonance, and other traditional forms of image acquisition. Designed to provide students with real-world exposure to practical applications of imaging and to reinforce human anatomy and physiology concepts from other courses. Four hours per week in clinical environments, observing clinicians in different medical environments to gain appreciation of current practices, imaging, and information systems. Participation in clinical noon conferences to further broaden exposure and understanding of medical problems. S/U grading. Mr. Kangarloo (F)

223A-223B-223C. Programming Laboratories for Medical Informatics I, II, III. (4-4-4) Lecture, two hours; laboratory, two hours. Designed for graduate students. Programming laboratories to support coursework in other medical 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 (HL7, DICOM). Letter grading. **223A.** Integrated with course 226 to reinforce concepts presented with practical experience. Projects focus on understanding medical networking issues and implementation of basic protocols for health care environment, with emphasis on use of DICOM. **223B.** Requisite: course 223A. Integrated with courses 224A and 227 to reinforce concepts presented with practical experience. Projects focus on medical image manipulation and decision support systems. **223C.** Requisite: course 223B. Integrated with courses 224B and 225 to reinforce concepts presented with practical experience. Projects focus on medical image storage and retrieval. 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: computed radiography (CR), computed tomography (CT), magnetic resonance (MR), and ultrasound (US). Emphasis on physics of image formation and image reconstruction methods. Overview of DICOM data models, basic medical image processing, content-based image retrieval, PACS, and image data management. Current research efforts, with focus on clinical applications and new types of information available. Geared toward nonphysicists to provide basic understanding of issues related to basic medical image acquisition. Letter grading. Mr. Sinha (W)

224B. Advanced Imaging for Informatics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 224A. Additional modalities and current research in imaging. Topics include nuclear medicine, functional magnetic resonance imaging (fMRI), MR diffusion/perfusion, and optical imaging, with focus on image analysis and visualization tools. Basic physics principles behind these newer imaging concepts, with exposure to seminal works. Current research efforts, with focus on clinical applications and new types of information available. Geared toward nonphysicists to provide basic understanding of issues related to advanced medical image acquisition and to understand functionality of imaging databases and image models facilitating sharing of imaging data for clinical and research purposes. Letter grading. Mr. Sinha (Sp)

M225. Bioseparations and Bioprocess Engineering. (4) (Same as Chemical Engineering CM225.) Lecture, four hours; outside study, eight hours. Requisites: Chemical Engineering 101C and 103, or Chemistry 156. 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. Letter grading. Mr. Monbouquette (W)

226. Medical Knowledge Representation. (4) Seminar, four hours; outside study, eight hours. Designed for graduate students. Issues related to medical knowledge representation and its application in health care processes. Topics include data structures used for representing knowledge (conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (data mining, statistical classifiers, and hierarchical classification), and basic information retrieval. Review of work in constructing ontologies, with focus on problems in implementation and definition. Common medical ontologies, coding schemes, and standardized indices/terminologies (SNOMEF, UMLS, MeSH, LOINC). Letter grading. Mr. Taira (Sp)

227. Medical Information Infrastructures and Internet Technologies. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to networking, communications, 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 (HIS, RIS, PACS). Advances in networking, such as wireless, Internet2/gigabit networks, peer-to-peer topologies. Introduction to security and encryption in networked environments. Letter grading. Mr. Bui (F)

228. Medical Decision Making. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and 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. S/U grading. Mr. Kangarloo (W)

230. Engineering Principles of Ultrasound. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to science and technology of acoustics in biological systems, starting with physical acoustics, acoustic wave (Helmholtz) equation, acoustic propagation and scattering in homogeneous and inhomogeneous media, and acoustic attentuation and davitation phenomena. Acoustic impedance, equivalent circuits, and network models. Electroacoustic transducers (piezoelectric and MEMS) and radiators. Acoustic generation, modulation, and pulse forming. Acoustic noise mechanisms. Receiving and processing of acoustic waves in presence of noise. Letter grading. Mr. Brown (F)

CM240. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM240.) Lecture, four hours; outside study, eight hours. Requisites: Civil Engineering 108 or Mechanical and Aerospace Engineering 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 generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading. Mr. Gupta (W)

C241L. Biomechanics Laboratory. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Requisite: course CM140 or Mechanical and Aerospace Engineering 156A. Hands-on laboratory pertaining to mechanical testing and analysis of long bone specimens. Students, working in pairs, engage in all aspects of procedures. Fundamentals include design and fabrication of signal processing circuitry for use in data acquisition process, including bridge completion circuits, amplifiers, and passive filters; computerized data acquisition using Lab View and A/D input/output (I/O) board; strain measurements on metallic and bone specimens. Finite element analysis of structure under investigation; comparison of experimental, theoretical, and computational results. Concurrently scheduled with course C141L. Letter grading.

CM245. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM245.) Lecture, four hours; discussion, one hour; outside study, eight hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics 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 applications of imaging for a range of modalities. Practical experience provided through a series of imaging laboratories. Letter grading.

M250A. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Electrical Engineering M250A and Mechanical and Aerospace Engineering M280.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M150L. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. Judy (W)

M250B. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Electrical Engineering M250B and Mechanical and Aerospace Engineering M282.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M250A. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Wu (Sp)

C251. Nanofabrication of Biomedical Systems Using Nonconventional Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: course M150L (or Electrical Engineering M150L), M250B. Use of nontraditional substrates and materials in fabrication of biomedical nanosystems. Materials and fabrication issues, post-processing integration, compatibility with standard processes, and standard fabrication environment. Packaging concerns. Imaging and diagnostics techniques. Reliability issues. Concurrently scheduled with course C151. Letter grading. Mr. Montemagno (W)

257. Engineering Mechanics of Motor Proteins and Cytoskeleton. (4) Lecture, four hours; outside study, eight hours. Requisites: Mathematics 32A, 32B, 33A, 33B, Life Sciences 3, Physics 1A, 1B, 1C. Introduction to physics of motor proteins and cytoskeleton: mass, stiffness and damping of proteins, thermal forces and diffusion, chemical forces, polymer mechanics, structures of cytoskeletal filaments, mechanics of cytoskeleton, polymerization of cytoskeletal filaments, force generation by cytoskeletal filaments, active polymerization, motor protein structure and operation. Emphasis on engineering perspective. Letter grading. Mr. Montemagno (Sp)

M259H. Biomechanics of Traumatic Injury. (4) (Same as Environmental Health Sciences M259H.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to applied biomechanics of accidental injury causation and prevention; discussion of mechanisms of injury that result in bone and soft tissue trauma; discussion of mechanisms of healing for effective rehabilitation after traumatic injury. Letter grading. Mr. Liu (W)

M260. Neuroengineering. (4) (Formerly numbered 260.) (Same as Neuroscience M206.) Lecture, four hours; laboratory, three hours. Requisites: Mathematics 32A, Molecular, Cell, and Developmental Biology 100, 171. Introduction to principles and technologies of neural recording and stimulation. Neurophysiology; clinical electrophysiology (EEG, evoked potentials, inverse problem, preoperative brain recording), extracellular microelectrodes and recording (field potentials and single units), chronic recording with extracellular electrodes; electrode biocompatibility, tissue damage, electrode and cable survival; intracellular recording and glass pipettes electrodes, iontophoresis; imaging neural activity (Ca imaging, voltage-sensitive dyes), intrinsic optical imaging; MRI, fMRI. Letter grading. Mr. Judy (Sp)

M261A-M261B-M261C. Evaluation of Research Literature in Neuroengineering. (2-2-2) (Same as Neuroscience M212A-M212B-M212C.) Discussion, two hours. Critical discussion and analysis of current literature related to neuroengineering research. S/U grading.

M263. Neuroanatomy: Structure and Function of Nervous System. (4) (Formerly numbered M263A-M263B.) (Same as Neuroscience M203.) Lecture, three hours; discussion/laboratory, three hours. Anatomy of central and peripheral nervous system 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, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C170. Letter grading. Mr. Grundfest (F)

C270L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) 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 simulations of light propagation in tissue, measuring absorption spectra of tissue/tissue phantoms, making tissue phantoms, determination of optical properties of different tissues, techniques of temperature distribution measurements. Concurrently scheduled with course C170L. Letter grading.

C271. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) Lecture, four hours; outside study, eight hours. Requisite: course C270. Designed for physical sciences, life sciences, and engineering majors. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biologic media. Concurrently scheduled with course C171. Letter grading. Mr. Grundfest (W)

CM280. Introduction to Biomaterials. (4) (Same as Materials Science CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 14. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (W)

C281. Biomaterials-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisite: course CM280. In-depth exploration of host cellular response to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C181. Letter grading. Mr. Wu (Sp)

282. Biomaterial Interfaces. (4) Lecture, four hours; laboratory, eight hours. Requisite: course CM180 or CM280. Function, utility, and biocompatibility of biomaterials depend critically on their surface and interfacial properties. Discussion of morphology and composition of biomaterials and nanoscales, mesoscales, and macroscales, techniques for characterizing structure and properties of biomaterial interfaces, and methods for designing and fabricating biomaterials with prescribed structure and properties in vitro and in vivo. Letter grading. Ms. Maynard (W)

C285. Introduction to Tissue Engineering. (4) Lecture, three hours; outside study, nine hours. Requisites: course CM102 or 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 C185. Letter grading. Mr. Wu (Sp)

CM286L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Formerly numbered CM296L.) (Same as Computer Science CM286L.) Lecture, two hours; laboratory, two hours. Requisite: course M186B. Special laboratory techniques and experience in biocybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Comprehensive experiment design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM186L. Letter grading. Mr. DiStefano

295A-295Z. Seminars: Research Topics in Biomedical Engineering and Bioengineering. (1 to 4)

Seminar, one to four hours. Limited to biomedical engineering graduate students. Advanced study and analysis of current topics in bioengineering. Discussion of current research and literature in research specialty of faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit. S/U grading:

295A. Nanotechnology Research.

295B. Biomaterials and Tissue Engineering Research.

295C. Minimally Invasive and Laser Research.

295D. Hybrid Device Research.

295E. Molecular Cell Bioengineering Research.

295F. Biopolymer Materials and Chemistry.

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

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

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Same as Computer Science M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296A. Recommended: course M296B. Research techniques and experience on special topics involving models, modeling methods, and model/computing in biological and medical sciences. Review and critique of literature. Research problem searching and formulation. Approaches to solutions. Individual M.S.- and Ph.D.-level project training. Letter grading. Mr. DiStefano (Sp)

M296D. Introduction to Computational Cardiology. (4) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course M186B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.
Mr. Kogan (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. Letter grading.

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

375. Teaching Apprentice Practicum. (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 the University. May be repeated for credit. S/U grading.

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 12) 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 Examinations. (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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Vasilios I. Manousiouthakis, Ph.D., *Chair*
James C. Liao, Ph.D., *Vice Chair*

Professors

Panagiotis D. Christofides, Ph.D.
Yoram Cohen, Ph.D.
James F. Davis, Ph.D., *Associate Vice Chancellor*
Sheldon K. Friedlander, Ph.D. *(Ralph M. Parsons Professor of Chemical Engineering)*
Robert F. Hicks, Ph.D.
Louis J. Ignarro, Ph.D. *(Nobel laureate)*
James C. Liao, Ph.D.
Vasilios I. Manousiouthakis, Ph.D.
Harold G. Monbouquette, Ph.D.
Selim M. Senkan, Ph.D.

Professors Emeriti

Eldon L. Knuth, Ph.D.
Ken Nobe, Ph.D.
William D. Van Vorst, Ph.D.
A.R. Frank Wazzan, Ph.D., *Dean Emeritus*

Associate Professor

Jane P. Chang, Ph.D. *(William Frederick Seyer Term Professor of Materials Electrochemistry)*

Assistant Professors

Gerassimos Orkoulas, Ph.D.
Tatiana Segura, Ph.D.
Yi Tang, Ph.D.

Scope

The Department of Chemical and Biomolecular Engineering conducts undergraduate and graduate programs of teaching and research that focus on the areas of cellular/molecular bioengineering, systems engineering, and semiconductor manufacturing and span the general themes of energy/environment and nanoengineering. Aside from the fundamentals of chemical engineering (applied mathematics, thermodynamics, transport phenomena, kinetics, reactor engineering and separations), particular emphasis is on genomics and proteomics, biochips, metabolic engineering, biosynthesis, bio-nano-technology, biomaterials, air pollution, combustion, environmental multimedia modeling, pollution prevention, aerosol processes, cryogenics, combinatorial catalysis, molecular simulation, process modeling/simulation/control/optimization/integration/synthesis, membrane science, semiconductor processing, chemical vapor deposition, plasma processing and simulation, electrochemistry corrosion, and polymer engineering.

Students are trained in the fundamental principles of these fields while learning a sensitivity to society's needs–a crucial combination in addressing the question of how industry can grow and innovate 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 curriculum, as well as bioengineering, biomedical engineering, environmental, and semiconductor manufacturing 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 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 alumni who demonstrate (1) the ability to 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) an understanding and sensitivity to social, ethical, environmental, and economical issues involving chemical engineering practice and an understanding of the role of chemical engineers in sustainable development, (3) successful participation 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) the ability to build on their undergraduate-level scientific knowledge and engineering skills through graduate study in the sciences and engineering and through success as professionals in diverse fields, including business, medicine, and environmental protection, as well as chemical and biomolecular engineering.

Chemical Engineering B.S.

The ABET-accredited chemical engineering curriculum provides a high quality, professionally oriented education in modern chemical engineering. The bioengineering, biomedical engineering, environmental, and semiconductor manufacturing options exist as subsets of courses within the accredited curriculum. Balance is sought between science and engineering practice.

The Major

Course requirements are as follows (202 minimum units required):

1. Three general engineering courses: Chemical Engineering M105A, Civil and Environmental Engineering 108, Electrical Engineering 100
2. Chemical Engineering 100, 101A, 101B, 101C, 102, 103, 104A, 104B, 106, 107, 108A, 108B, 109; Chemistry and Biochemistry 30A, 30B, 30BL, 113A, 171
3. Two elective courses from Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C125, C140, and three upper division chemistry elective courses (except Chemistry and Biochemistry 110A). An upper division life or physical sciences course may be substituted for one chemistry elective with the approval of the faculty adviser
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Bioengineering Option

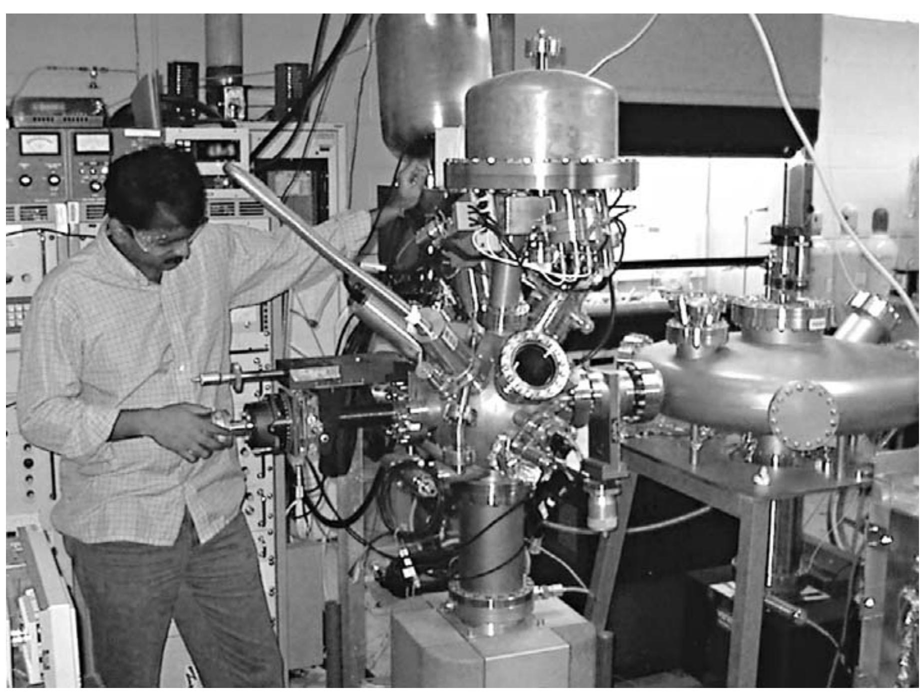
Course requirements are as follows (204 or 205 minimum units required):

1. Three general engineering courses: Chemical Engineering M105A, Civil and Environmental Engineering 108, Electrical Engineering 100
2. Chemical Engineering 100, 101A, 101B, 101C, 102, 103, 104A, 104B, 106, 107, 108A, 108B, 109; Chemistry and Biochemistry 30A, 30B, 30BL, 153A, 156; Life Sciences 4 or Microbiology, Immunology, and Molecular Genetics 101
3. Two elective courses from Chemical Engineering C115, C125, CM145 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser); one upper division ecology and evolutionary biology or microbiology, immunology, and molecular genetics or molecular, cell, and developmental biology elective that requires one year of chemistry as a requisite
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Life Sciences 2, 3; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Biomedical Engineering Option

Course requirements are as follows (203 or 204 minimum units required):

1. One general engineering course: Chemical Engineering M105A
2. Chemical Engineering 100, 101A, 101B, 101C, 102, 103, 104A, 104B, 106, 107, 108A, 108B, 109; Chemistry and Biochemistry 30A, 30B, 30BL, 153A, 156; Life Sciences 4 or Microbiology, Immunology, and Molecular Genetics 101
3. Two elective courses from Chemical Engineering C115, C125, CM145 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser); one upper division ecology and evolutionary biology or microbiology, immunology, and molecular genetics or molecular, cell, and developmental biology elective that requires one year of chemistry as a requisite and contains a laboratory component (laboratory component may be taken from a separate course)
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Life Sciences 1, 2, 3; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details



UHV surface analytical system.

Environmental Option

Course requirements are as follows (206 minimum units required):

1. Three general engineering courses: Chemical Engineering M105A, Civil and Environmental Engineering 108, Electrical Engineering 100
2. Chemical Engineering 100, 101A, 101B, 101C, 102, 103, 104A, 104B, 106, 107, 108A, 108B, 109; Atmospheric and Oceanic Sciences 104; Chemistry and Biochemistry 30A, 30B, 30BL, 113A, 171
3. Two elective courses from Chemical Engineering 113, C118, C119, C140 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser) and three advanced chemistry electives in the environmental field from Atmospheric and Oceanic Sciences M203A, Chemistry and Biochemistry 103, 110B, Ecology and Evolutionary Biology M127, Environmental Health Sciences 240, 261 (other advanced chemistry courses may be selected in consultation with the faculty adviser)
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Semiconductor Manufacturing Option

Course requirements are as follows (206 minimum units required):

1. Three general engineering courses: Chemical Engineering M105A, Electrical Engineering 100, Materials Science and Engineering 14
2. Chemical Engineering 100, 101A, 101B, 101C, 102, 103,104A, 104C, 106, 107, 108A, 108B, 109; Chemistry and Biochemistry 30A, 30B, 30BL, 113A, 171; Electrical Engineering 2; Materials Science and Engineering 120
3. Two elective courses from Chemical Engineering C112, 113, C114, C116, C118, C119, C140 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser) and two chemistry elective courses (except Chemistry and Biochemistry 110A)
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the “Publications” link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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

Chemical Engineering M.S.

Areas of Study

Consult the department.

For the semiconductor manufacturing field, the program requires that students have advanced knowledge, assessed in a comprehensive examination, of processing semiconductor devices on the nanoscale.

Course Requirements

The requirements for an M.S. degree are a thesis, nine courses (36 units), and a 3.0 grade-point average in the graduate courses. Chemical Engineering 200, 210, and 220 are required for all M.S. degree candidates. Two courses must be taken from offerings in the Chemical and Biomolecular Engineering Department, while two Chemical Engineering 598 courses involving work on the thesis may also be selected. The remaining two courses may be taken from those offered by the department or any other field in life sciences, physical sciences, mathematics, or engineering. At least 24 units must be in letter-graded 200-level courses.

All M.S. degree candidates must enroll in the seminar, Chemical Engineering 299, during each quarter in residence.

A program of study that encompasses these requirements must be submitted to the departmental Student Affairs Office for approval before the end of the student’s second quarter 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 M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 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, 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, 234, C240, Electrical Engineering 124, 221B, 223, 224, Materials Science and Engineering 221, 223, 245C.

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 quarter in residence.

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

Comprehensive Examination Plan

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

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

Thesis Plan

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

Chemical Engineering Ph.D.

Major Fields or Subdisciplines

Consult the department.

Course Requirements

All Ph.D. students must take six courses (24 units), including Chemical Engineering 200, 210, and 220. Two additional courses must be taken from those offered by the Chemical and Biomolecular Engineering Department. The third course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. All of these units must be in letter-graded 200-level courses. Students are encouraged to take more courses in their field of specialization. The minor field courses should be selected in consultation with the research adviser and approved by the graduate 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 quarter after successful completion of the preliminary oral examination.

All Ph.D. students are required to enroll in the Chemical and Biomolecular Engineering Department's graduate seminar during each quarter in residence.

For information on completing the Engineer degree, see Engineering Schoolwide Programs.

Written and Oral 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, chemical kinetics, and reactor design. The examination is held at the beginning of Winter Quarter. 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 master'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. The 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 explanation of the approach to be followed to solve the problem. Students first present their ideas for the dissertation research at a precandidacy seminar administered by departmental faculty members of the doctoral committee. The seminar is held during the early part of the Winter Quarter of the second year in residence. Following the seminar, students submit the dissertation research proposal to the doctoral committee. The written examination is due in the seventh week of the Winter Quarter.

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 within two weeks of 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 at UCLA in the student's major department in HSSEAS. The "outside" member must be a UCLA faculty member outside the student's major department.

Facilities

Biomolecular Engineering Laboratories

The Biomolecular Engineering laboratories are equipped for cutting-edge genetic, molecular, and cellular bioengineering 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 multiangle laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and (10) phosphoimager 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 uing DNA microarrays and real-time 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, cholestrol-lowering, and/or antibiotic activities. Biosensors are being micromachined for detecting neurotransnmitters in vivo. New biosensing schemes also are being invented for the detection of endocrine disrupting chemicals in the environment and for the high-throughput screening of drug candidates. Naturally occurring protein nanocapsules are being redesigned at the genetic level for applications in drug delivery and materials synthesis. Finally, the enzymology of extremely thermophilic microbes is being explored for applications in specialty chemical synthesis.

Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory

The Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory is equipped with advanced research tools for experimental and computational studies in chemical kinetics, catalytic materials, and combustion, including quadrupole mass spectrometer (QMS) systems to sample reactive systems with electron impact and photoionization capabilities; several fully computerized gas chromatograph/mass spectrometer (GC/MS) systems for gas analysis; fully computerized array channel microreactors for catalyst discovery and optimization; several flat premixed and diffusion flame burners and flow reactors to study combustion and other fast reactions; a laser photoionization (LP) time-of-flight (TOF) mass spectrometer for the 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 synthesizing and processing novel electronic materials for their applications in microelectronics, micro-optoelectronics, and microelectromechanical systems (MEMS). Areas of interest include novel dielectric materials, advanced thermal and plasma processing, surface and interface kinetics, and solid-state electronic devices and chemical and biological MEMS fabrication. 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; a surface analytical facility including X-ray photoelectron spectroscopy, Auger electron spectroscopy, ultra-violet photoelectron spectroscopy, reflection high energy electron diffraction, spectroscopic ellipsometry, 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.

Nanoparticle Technology and Air Quality Engineering Laboratory

Modern particle technology focuses on particles in the nanometer (nm) size range with applications to air pollution control and commercial production of fine particles. Particles with diameters between 1 and 100 nm are of interest both as individual particles and in the form of aggregate structures. The Nanoparticle Technology and Air Quality Engineering Laboratory is equipped with instrumentation for online measurement of aerosols, including optical particle counters, electrical aerosol analyzers, and condensation particle counters. A novel low-pressure impactor designed in the laboratory is used to fractionate particles for morphological analysis in size ranges down to 50 nm (0.05 micron). Also available is a high-volumetric flow rate impactor suitable for collecting particulate matter for chemical analysis. Several types of specially designed aerosol generators are also available, including a laser ablation chamber, tube furnaces, and a specially designed aerosol microreactor.

Concern with nanoscale phenomena requires the use of advanced systems for particle observation and manipulation. Students have direct access to modern facilities for transmission and scanning electron microscopy. Located near the laboratory, the Electron Microscopy facilities staff provide instruction and assistance in the use of these instruments. Advanced electron microscopy has recently been used in the laboratory to make the first systematic studies of atmospheric nanoparticle chain aggregates. Such aggregate structures have been linked to public health effects and to the absorption of solar radiation. A novel nanostructure manipulation device, designed and built in the laboratory, makes it possible to probe the behavior of nanoparticle chain aggregates of a type produced commercially for use in nanocomposite materials; these aggregates are also released by sources of pollution such as diesel engines and incinerators.

Polymer and Separations Research Laboratory

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

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

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

Sheldon K. Friedlander, Ph.D. (Illinois, 1954)
Aerosol dynamics, nanoparticle technology, diffusion and interfacial transfer, air pollution control, atmospheric aerosols

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

Vasilios 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, biotechnology of extreme thermophiles, nanotechnology

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

Professors Emeriti

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

Ken Nobe, Ph.D. (UCLA, 1956)
Electrochemistry, corrosion, electrochemical kinetics, electrochemical energy conversion, electrodeposition of metals and alloys, electrochemical treatment of toxic wastes, bioelectrochemistry

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

Associate Professor

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

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)
Gene therapy, tissue engineering, substrate-mediated non-viral DNA delivery

Yi Tang, Ph.D. (Cal Tech, 2002)
Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibiotics/antitumor products

Lower Division Courses

2. Technology and the 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 (CO_2 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 life-cycle methods for evaluating environmental impact of processes and products. P/NP or letter grading. Mr. Manousiouthakis (Sp)

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

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

Upper Division Courses

100. 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. Letter grading. Mr. Monbouquette (F)

101A. Momentum Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course M105A, Mathematics 33A, 33B. Corequisite: course 109. Introduction to analysis of fluid flow in systems of interest to chemical engineering practice. Fundamentals of momentum transport, Newton law of viscosity, Navier/Stokes equations, interphase momentum transport and friction factors, flows in conduits and around submerged objects. Letter grading. Mr. Cohen, Mr. Friedlander (F)

101B. Heat Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101A. Introduction to analysis of heat transfer in systems of interest to chemical engineering practice. Fundamentals of thermal energy transport, Fourier law of heat conduction, forced and free convection, radiation, interphase heat transfer, heat exchanger analysis. Letter grading. Mr. Hicks (W)

101C. Mass Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101B, 102. 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 reacting flows, interphase mass transfer, multicomponent systems. Letter grading. Mr. Hicks (Sp)

102. Chemical Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 100, M105A. Thermodynamic properties of pure substances and solutions. Phase equilibrium. Chemical reaction equilibrium. Letter grading. Mr. Nobe (W)

103. Separation Processes. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 100, 101B, 102. 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. Hicks (Sp)

104A. Chemical Engineering Laboratory I. (6) Lecture, two hours; laboratory, eight hours; outside study, four hours; other, four hours. Requisites: courses 100, 101B, 102. Measurements of temperature, pressure, flow rate, viscosity, and fluid composition in chemical processes. Methods of data acquisition, equipment selection and fabrication, and laboratory safety. Development of written and oral communication skills. Letter grading. Mr. Hicks (W,Sp)

104B. Chemical Engineering Laboratory II. (6) Lecture, two hours; laboratory, eight hours; outside study, four hours; other, four hours. Requisites: courses 101C, 103, 104A. Course consists of four experiments in chemical engineering unit operations, each of two weeks duration. Students present their results both written and orally. Written report includes sections on theory, experimental procedures, scaleup and process design, and error analysis. Letter grading. Mr. Senkan (F,W)

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, six hours. Requisites: courses 101C, 104A, Electrical Engineering 2, Materials Science 120. 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, metallization, and statistical design of experiments and error analysis. Presentation of student results in both written and oral form. Letter grading. Ms. Chang, Mr. Hicks (Sp)

104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours. Requisites: courses 101C, 104A, Electrical Engineering 2, Materials Science 120. 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, and metallization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Ms. Chang, Mr. Hicks (Sp)

104D. Molecular Biotechnology Lecture: From Gene to Product. (2) Lecture, two hours. Requisites: courses 101C, 103, 104A. Corequisite: course 104DL. 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. Mr. Liao (W)

104DL. Molecular Biotechnology Laboratory: From Gene to Product. (4) Laboratory, eight hours. Requisites: courses 101C, 103, 104A. 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. Mr. Liao (W)

M105A. Introduction to Engineering Thermodynamics. (4) (Same as Mechanical and Aerospace Engineering M105A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Concepts of equilibrium, temperature, and reversibility. First law and concept of energy; second law and concept of entropy. Equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading. Mr. Nobe (W,Sp)

106. Chemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 100, 101C, 102. 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; outside study, eight hours. Requisites: courses 101C, 103, 106. 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. Manousiouthakis (W)

108A. Process Economics and Analysis. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 104B, 106. Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purpose of designing chemical processes and evaluating alternatives. Letter grading. Mr. Manousiouthakis (W)

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 106, 108A, and either Civil Engineering 15 or Mechanical and Aerospace Engineering 20. Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading. Mr. Manousiouthakis (Sp)

109. Mathematical Methods in Chemical Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: working knowledge of Fortran programming. Discussion of theory and applications of mathematics to chemical engineering problems, with focus on numerical and analytical techniques encompassing linear and nonlinear algebraic equations, finite difference methods, and ordinary and partial differential equations. Letter grading. Mr. Christofides (F)

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

C111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102 (or Materials Science 130), M105A. Fundamentals of cryogenics and cryoengineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C211. Letter grading. Mr. Manousiouthakis (F)

C112. Polymer Processes. (4) (Formerly numbered 112.) Lecture, four hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting a 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 C212. Letter grading. Mr. Cohen (Sp)

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

C114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102 (or Materials Science 130), M105A. 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, electrosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C214. Letter grading. Mr. Nobe (F)

C115. Biochemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101C and 106, or Chemistry 156. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course CM215. Letter grading. Mr. Liao, Mr. Monbouquette (Sp)

C116. 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 microelectronics devices. Topics include classification of crystals and surfaces, analysis of structure and composition of crystals and their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading. Ms. Chang, Mr. Hicks (F)

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

C119. Pollution Prevention for Chemical Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 108A. Systematic methods for design of environment-friendly processes. Development of the methods at molecular, unit-operation, and network levels. Synthesis of mass exchange, heat exchange, and reactor networks. Concurrently scheduled with course C219. Letter grading. Mr. Manousiouthakis (Sp)

C125. Bioseparations and Bioprocess Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101C and 103, or Chemistry 156. 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. Liao, Mr. Monbouquette (W)

C140. Fundamentals 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 production of fine particles, and catalysis. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C240. Letter grading.
Mr. Friedlander (F or W)

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, 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

188. Special Courses in Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in chemical engineering for undergraduate students that are taught on experimental or temporary basis, such as courses 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 Engineering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Letter grading.

199. Directed Research in Chemical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation of selected topic under guidance of faculty mentor. 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 102. 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 techniques for classical molecular systems. Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading.

210. Advanced Chemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101C, 106. Principles of chemical reactor analysis and design. Particular emphasis on simultaneous effects of chemical reaction and mass transfer on noncatalytic and catalytic reactions in fixed and fluidized beds. Letter grading.
Mr. Senkan (W)

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102 (or Materials Science 130), M105A. Fundamentals of cryogenics and cryoengineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading. (F)

C212. Polymer Processes. (4) Lecture, four hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting a reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Polymers in biomedical applications and in microelectronics. Concurrently scheduled with course C112. Letter grading.
Mr. Cohen (Sp)

C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102 (or Materials Science 130), M105A. 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, electrosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. Mr. Nobe (F)

CM215. Biochemical Reaction Engineering. (4) (Same as Biomedical Engineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101C and 106, or Chemistry 156. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course C115. Letter grading.
Mr. Liao, Mr. Monbouquette (W)

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

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

C219. Pollution Prevention for Chemical Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 108A. Systematic methods for design of environment-friendly processes. Development of the methods at molecular, unit-operation, and network levels. Synthesis of mass exchange, heat exchange, and reactor networks. Concurrently scheduled with course C119. Letter grading. 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, Mr. Friedlander (F)

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

CM225. Bioseparations and Bioprocess Engineering. (4) (Same as Biomedical Engineering M225.) Lecture, four hours; outside study, eight hours. Requisites: courses 101C and 103, or Chemistry 156. 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 C125. Letter grading.
Mr. Liao, Mr. Monbouquette (Sp)

230. Reaction Kinetics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 106, 200. Macroscopic descriptions: reaction rates, relaxation times, thermodynamic correlations of reaction rate constants. Molecular descriptions: kinetic theory of gases, models of elementary processes. Applications: absorption and dispersion measurements, unimolecular reactions, photochemical reactions, hydrocarbon pyrolysis and oxidation, explosions, polymerization. Letter grading. Mr. Senkan (Sp)

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

232. Combustion Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 106, 200, or Mechanical and Aerospace Engineering 132A. Fundamentals: change equations for multicomponent reactive mixtures, rate laws. Applications: combustion, including burning of (1) premixed gases or (2) condensed fuels. Detonation. Sound absorption and dispersion. Letter grading. Mr. Senkan (Sp)

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

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

C240. Fundamentals 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 production of fine particles, and catalysis. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C140. Letter grading. Mr. Friedlander (F)

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

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

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

260. Non-Newtonian Fluid Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M105A. Principles of non-Newtonian fluid mechanics. Stress constitutive equations. Rheology of polymeric liquids and dispersed systems. Applications in viscometry, polymer processing, biorheology, oil recovery, and drag reduction. Letter grading. Mr. Cohen (Sp)

270. Chemical Engineering Principles of Semiconductor Manufacturing. (4) Lecture, four hours; outside study, eight hours. Limited to graduate chemical engineering students in M.S. semiconductor manufacturing option. Fundamentals of unit operations, transport phenomena, chemical kinetics, thermodynamics, and control in context of semiconductor materials processing. Letter grading. Ms. Chang (W)

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

M280A. Linear Dynamic Systems. (4) (Same as Electrical Engineering M240A and Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear time-invariant (LTI) and time-varying (LTV) 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.

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.

M282A. Nonlinear Dynamic Systems. (4) (Same as Electrical Engineering M242A and Mechanical and Aerospace Engineering M272A.) Lecture, four hours; outside study, eight hours. Requisite: course M280A 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. Liapunov 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 M280A, M282A. Designed for graduate students. Introduction to advanced dynamical analysis and controller synthesis methods for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Banach and Hilbert spaces, semigroup theory, convergence theory in function spaces), (2) nonlinear model reduction (linear and nonlinear Galerkin 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

284A. Optimization in Vector Spaces. (4) Lecture, four hours; outside study, eight hours. Requisites: Electrical Engineering 236A, 236B. Review of functional analysis concepts. Convexity, convergence, continuity. Minimum distance problems for Hilbert and Banach spaces. Lagrange multiplier theorem in Banach spaces. Nonlinear duality theory. Letter grading. Mr. Manousiouthakis

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

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

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

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

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at the University. May be repeated for credit. S/U grading. (F,W,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 in M.S. semiconductor manufacturing option. Reading and preparation for M.S. comprehensive examination. S/U grading.

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

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) 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 for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate chemical engineering students. Supervised independent research for M.S. candidates, including thesis prospectus. S/U grading.

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

Civil and Environmental Engineering

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Professors Emeriti

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Jennifer A. Jay, Ph.D.
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Ertugrul Taciroglu, Ph.D.
Jian Zhang, Ph.D.

Senior Lecturers

George J. Tauxe, M.S., *Emeritus*
Christopher Tu, Ph.D.

Adjunct Professors

Thomas C. Harmon, Ph.D.
Ne-Zheng Sun, Ph.D.

Adjunct Associate Professors

Patrick J. Fox, Ph.D.
Daniel E. Pradel, Ph.D.
Thomas Sabol, Ph.D.

Scope

The civil and environmental engineering programs at UCLA include structural engineering, structural mechanics, geotechnical engineering, earthquake 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.

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.

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.

Civil Engineering B.S.

The Major

Course requirements are as follows (185 minimum units required):

1. Seven core courses: Chemical Engineering M105A or Mechanical and Aerospace Engineering M105A, Civil and Environmental Engineering 1, 108, Electrical Engineering 103, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103
2. Civil and Environmental Engineering 120, 121, 130, 135A, 150, 151, 153; two courses in different major field areas involving a major design project selected from Civil and Environmental Engineering 123, 135L, 144, 147, 157B, 157C, 157L; Civil and Environmental Engineering 110 and Mechanical and Aerospace Engineering 182A
3. Twenty-four elective units, to be selected from the courses listed below, which must include 8 units of laboratory in at least two major field areas and at least 12 units of design:

   Engineering Mechanics. Civil and Environmental Engineering 130L, Mechanical and Aerospace Engineering 166C, 168

   Geotechnical Engineering. Civil and Environmental Engineering 123, 125, 128L, Earth and Space Sciences 100, 139

   Structures. Civil and Environmental Engineering 135B, 135C, 135L, 137, 137L, 141, 142, 142L, 143, 144, 147

   Systems Analysis. Civil and Environmental Engineering 106A

   Transportation Engineering. Civil and Environmental Engineering 180

   Water Resources and Environmental Engineering. Civil and Environmental Engineering 154, 155, 156A, 156B, 157B, 157C, 157L, 163, 164, M166, 166L
4. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 15; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the “Publications” link at http://www.gdnet

.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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.

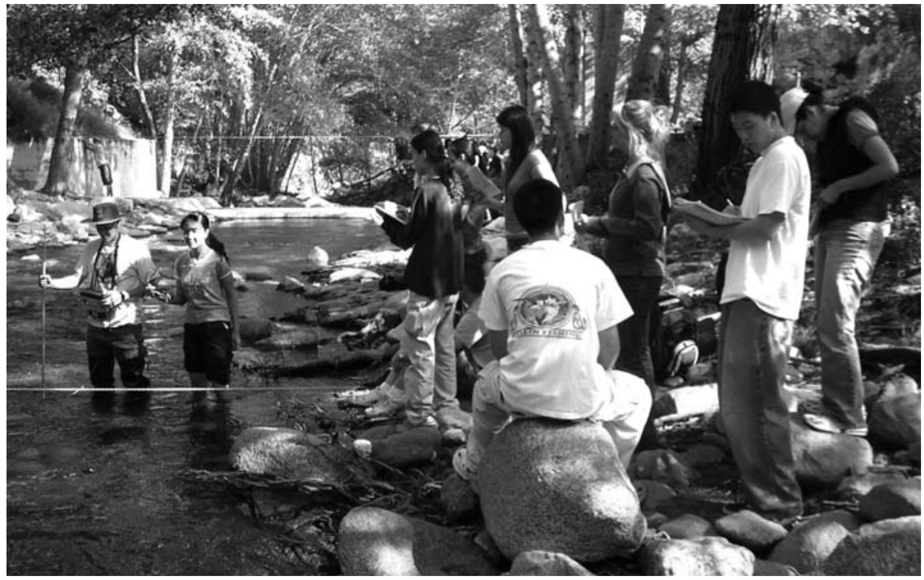
Course Requirements

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 M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 105D, 199.

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



Civil and Environmental Engineering students learn streamgauging in the Arroyo Seco channel as part of the Hydrologic Analysis and Design course.

Environmental Engineering

Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 32A, 33A; Mechanical and Aerospace Engineering 103, M105A; Civil and Environmental Engineering 150 or 151, 153; Physics 1A, 1B, 4AL, 4BL.

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

Elective Courses. Civil and Environmental Engineering 110, 155, 157B, 157C, 163, 164, M166, 253, 258A, 263A, 263B, 265A, 265B, 266; 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: Civil and Environmental Engineering 150, 226, 250A, 250B, 250C, 250D, 252, 260, M262A, M262B, Chemical Engineering 101C or Mechanical and Aerospace Engineering 105D, Chemical Engineering 106, 210, C218, 220, C240, Chemistry and Biochemistry 110A, 110B, Computer Science 270A, 271A, 271B, Electrical Engineering 236A, 236B, 236C, Environmental Health Sciences 240, 252D, 255, 264, 410A, 410B.

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, 125, 128L, 222, 225, 226, 227, 228L.

Elective Courses. General: Earth and Space Sciences 139, 222, Mechanical and Aerospace Engineering M256A; earthquake/structural engineering: Civil and Environmental Engineering 135A, 135B, 137, 235A, 235B, 235C, 244, 246, Mechanical and Aerospace Engineering 174; environmental engineering: Civil and Environmental Engineering 153, 164, 250B, 250C.

Hydrology and Water Resources Engineering

Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L, Mathematics 32A, 32B, 33A; Mechanical and Aerospace Engineering 103, M105A; Civil and Environmental Engineering 150 or 151, 153; Physics 1A, 1B, 4AL, 4BL.

Required Graduate Courses. Minimum of five courses must be selected from Civil and Environmental Engineering 250A, 250B, 250C, 250D, 252, 253, 260, 265A, 265B.

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.

Students may petition the department for permission to pursue programs of study that differ from the above norms.

Structural/Earthquake Engineering

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

Required Graduate Courses. Civil and Environmental Engineering 235A, 246; at least three of the following courses: Civil and Environmental Engineering 241, 242, 243A, 243B, 244, 247, 248.

Elective Courses. Undergraduate: No more than two courses from Civil and Environmental Engineering 125, 135C, 137, 143; geotechnical area: Civil and Environmental Engineering 220, 221, 222, 223, 225, 227; general graduate: Civil and Environmental Engineering M230A, M230B, 232, 233, 235B, 235C, 236, 238, M239, 241, 242, 243A, 243B, 244, 247, 248, Mechanical and Aerospace Engineering M256A, 269B.

Structural Mechanics

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

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

Elective Courses. Undergraduate: No more than two courses from Civil and Environmental Engineering 135C, 137, 137L; graduate: Civil and Environmental Engineering M230A, M230B, 233, 234, 235C, 238, M239, 244, 246, 247, 248, Mechanical and Aerospace Engineering M256A, 269B.

Comprehensive Examination Plan

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

Thesis Plan

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

Civil Engineering Ph.D.

Major Fields or Subdisciplines

Environmental engineering, geotechnical engineering, hydrology and water resources engineering, structural/earthquake engineering, and structural mechanics.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may theoretically substitute coursework by examinations. However, students normally take courses to acquire the knowledge needed for the required written and oral preliminary examinations. The basic program of study for the Ph.D. degree is built around one major field and two minor fields. The major field has a scope corresponding to a body of knowledge contained in a detailed Ph.D. field syllabus available on request from the department office. Each minor field normally embraces a body of knowledge equivalent to three courses from the selected field, at least two of which are graduate courses. Grades of B— or better with a grade-point average of at least 3.33 in all courses included in the minor field, are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor fields are chosen 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 at UCLA in the student's major department in HSSEAS. The "outside" member must be a UCLA faculty member outside the student's major 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 engineering structures. Areas of research include laboratory investigations of soil behavior under static and dynamic loads, constitutive modeling of soil behavior, behavior of structural foundations under static and dynamic loads, soil improvement techniques, response of soil deposits and earth structures to earthquake loads, and the investigation of geotechnical aspects of environmental engineering.

Hydrology and Water Resources Engineering

Ongoing research 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, 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

1. *Experimental Fracture Mechanics Laboratory.* 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.
2. *Structural Design and Testing Laboratory.* 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.
3. *Reinforced Concrete Laboratory.* 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.
4. *Mechanical Vibrations Laboratory.* 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 servo-hydraulic 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.
5. *Environmental Engineering Laboratories.* 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.
6. *Soil Mechanics Laboratory.* For performing experiments to establish data required for soil classification, soil compaction, shear strength of soils, soil settlement, and consolidation characteristics of soils.
7. *Advanced Soil Mechanics Laboratory.* For presenting and performing advanced triaxial, simple shear, and consolidation soil tests. For demonstration of cyclic soil testing techniques and advanced data acquisition and processing.

Research Laboratories

1. *Experimental Mechanics Laboratory.* For supporting 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.
2. *Large-Scale Structure Test Facility.* For investigating 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.
3. *Soil Mechanics Laboratory.* For standard experiments and advanced research in geotechnical engineering, with equipment for static and dynamic triaxial and simple shear testing. Modem 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.

4. *Building Earthquake Instrumentation Network.* More than100 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 highrises 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.

5. *Environmental Engineering Laboratories.* 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.

Faculty Areas of Thesis Guidance

Professors

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

Jiann-Wen Ju, Ph.D. (UC Berkeley, 1986)
Damage mechanics, mechanics of composite materials, computational plasticity, and computational mechanics

Michael K. Stenstrom, Ph.D. (Clemson, 1976)
Process development and control for water and wastewater treatment plants

Keith D. Stolzenbach, Ph.D. (MIT, 1971)
Environmental fluid mechanics, fate and transport of pollutants, dynamics of particles

Mladen Vucetic, Ph.D. (Rensselaer, 1986)
Geotechnical engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties

William W-G. Yeh, Ph.D. (Stanford, 1967)
Hydrology and optimization of water resources systems

Professors Emeriti

Stanley B. Dong, Ph.D. (UC Berkeley, 1962)
Structural mechanics, structural dynamics, finite element methods, numerical methods and mechanics of composite materials

Lewis P. Felton, Ph.D. (Carnegie Institute of Technology, 1964)
Structural analysis, structural mechanics, automated optimum structural design, including reliability-based design

Michael E. Fourney, Ph.D. (Cal Tech, 1963)
Experimental mechanics, special emphasis on application of modern optical techniques

Gary C. Hart, Ph.D. (Stanford, 1968)
Structural engineering analysis and design of buildings for earthquake and wind loads, structural dynamics, and uncertainty and risk analysis of structures

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

Tung Hua Lin, D.Sc. (Michigan, 1953)
Plasticity and creep: micromechanics and constitutive relations of metals; elastic-plastic analysis of structures; creep analysis of structures

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

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

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

Lucien A. Schmit, Jr., M.S. (MIT, 1950)
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components

Lawrence G. Selna, Ph.D. (UC Berkeley, 1967)
Reinforced concrete, earthquake engineering

Associate Professors

Jonathan P. Stewart, Ph.D. (UC Berkeley, 1996)
Geotechnical engineering, earthquake engineering

John W. Wallace, Ph.D. (UC Berkeley, 1988)
Earthquake engineering, design methodologies, seismic evaluation and retrofit, large-scale testing laboratory and field testing

Assistant Professors

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

Terri S. Hogue, Ph.D. (Arizona, 2003)
Surface hydrology, hydroclimatology, rainfall-runoff modeling, operational flood forecasting, parameter estimation, model optimization techniques, sensitivity analysis, land-surface-atmosphere interactions, surface vegetation atmosphere transfer schemes (SVATS), and carbon flux modeling

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

Steven Margulis, Ph.D. (MIT, 2000)
Surface hydrology, hydrometeorology, remote sensing, data assimilation

Ertugrul Taciroglu, Ph.D. (Illinois, Urbana-Champaign, 1998)
Computational structural and solid mechanics and constitutive modeling of materials

Jian Zhang, Ph.D. (UC Berkeley, 2002)
Earthquake engineering, structural dynamics and mechanics, seismic protective devices and strategies, soil-structure interaction, and bridge engineering

Senior Lecturers

George J. Tauxe, M.S. (Cornell, 1937), *Emeritus*
Soil mechanics

Christopher Tu, Ph.D. (UC Davis, 1975)
Groundwater movement and surface water hydrology

Adjunct Professors

Thomas C. Harmon, Ph.D. (Stanford, 1992)
Physical and chemical treatment processes, mass transfer in aqueous systems, contaminant transport in porous media

Ne-Zheng Sun, Ph.D. (Shandong, 1965)
Mathematical modeling of groundwater flow and contaminant transport, water resources management, numerical analysis and optimization

Adjunct Associate Professors

Patrick J. Fox, Ph.D. (Wisconsin, Madison, 1992)
Flow through porous median, settlement analysis, soil properties and testing, environmental geotechnology, reinforced soil walls, discrete element modeling, and smoothed particle hydrodynamics.

Daniel E. Pradel, Ph.D. (U. Tokyo, 1987)
Soil mechanics and foundation engineering

Thomas Sabol, Ph.D. (UCLA, 1985)
Seismic performance and structural design issues for steel and concrete seismic force resisting systems; application of probabilistic methods to earthquake damage quantification

Lower Division Courses

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

15. Introduction to Computing for Civil Engineers. (4) Lecture, four hours; laboratory, eight hours; outside study, four hours. Introduction to computer programming using single language such as Fortran or MATLAB. Selected topics in programming, with emphasis on numerical techniques as applied to engineering programs. Letter grading.
Mr. Chen, Mr. Ju (F,W,Sp)

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

58SL. Wetlands and Water Quality Service Learning Course. (4) Lecture, three hours. Learning and teaching of basic water quality concepts and wetland functions in one of two middle school classrooms in Los Angeles. Topics include photosynthesis, respiration, basic water quality parameters (pH, dissolved oxygen, salinity, turbidity), basic contaminant chemistry and metal precipitation, and role of wetlands in microbial water quality. Field trip with middle school students to Ballona Wetlands. Letter grading.
Ms. Jay (W)

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

101. Statics. (2) Lecture, two hours; outside study, four hours. Requisites: Mathematics 31B, Physics 1B. Introduction to equilibrium principles for engineered systems. Study of internal forces and moments in beams, including relationships for shear, axial load, and moment diagrams. Introduction to support conditions and geometric properties of structural members. Letter grading. Mr. Ju (F)

106A. Problem Solving in Engineering Economy. (4) Lecture, four hours; outside study, eight hours. Designed for juniors/seniors. Problem-solving and decision-making framework for economic analysis of engineering projects. Foundation for understanding corporate financial practices and accounting. Decisions on capital investments and choice of alternatives for engineering applications in all fields. Introduction to use of engineering economics in analysis of inflation and public investments. Letter grading. Mr. Yeh (F)

108. Introduction to Mechanics of Deformable Solids. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A, Mechanical and Aerospace Engineering 102. Review of equilibrium principles; forces and moments transmitted by slender members. Concepts of stress and strain. Material constitution (stress-strain relations). Yield criteria. Structural applications to trusses, beams, shafts, columns, and pressure vessels. Letter grading. Mr. Ju (F,W,Sp)

110. Introduction to Probability and Statistics for Engineers. (4) (Formerly numbered 160.) Lecture, four hours; outside study, eight hours. Requisites: course 15, Mathematics 32A, 33A. Introduction to fundamental concepts and applications of probability and statistics in civil engineering, with focus on how these concepts are used in experimental design and sampling, data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distributions, functions of random variables, estimating parameters from observational data, regression, hypothesis testing, and Bayesian concepts. Letter grading. Mr. Margulis (Sp)

120. Principles of Soil Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Soil as a foundation for structures and as a material of construction. Soil formation, classification, physical and mechanical properties, soil compaction, earth pressures, consolidation, and shear strength. Letter grading. Mr. Vucetic (F)

121. Design of Foundations and Earth Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 120. Design methods for foundations and earth structures. Site investigation, including evaluation of soil properties for design. Design of footings and piles, including stability and settlement calculations. Design of slopes and earth retaining structures. Letter grading. Mr. Stewart (W)

123. Advanced Geotechnical Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 121. Analysis and design of earth dams, including seepage, piping, and slope stability analyses. Case history studies involving landslides, settlement, and expansive soil problems, and design of repair methodologies for those problems. Within context of above technical problems, emphasis on preparation of professional engineering documents such as proposals, work acknowledgements, figures, plans, and reports. Letter grading. Mr. Stewart (Sp)

125. Fundamentals of Earthquake Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 121 and either 137 or 222. Representations of earthquake ground motion, including response and Fourier spectra. Seismic design codes for building structures. Ground motion hazard analysis, including fault characterization, attenuation relationships, and site effects. Near fault ground motions. Time history selection. Letter grading. Mr. Stewart (Sp)

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

130. Elementary Structural Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Analysis of stress and strain, phenomenological material behavior, extension, bending, and transverse shear stresses in beams with general cross-sections, shear center, deflection of beams, torsion of beams, warping, column instability and failure. Letter grading. Mr. Taciroglu (W)

130L. Experimental Structural Mechanics. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 130. Lectures and laboratory experiments in various structural mechanics testing of metals, plastics, and concrete. Direct tension. Direct compression. Ultrasonic nondestructive evaluation. Elastic buckling of columns. Fracture mechanics testing and fracture toughness. Splitting and flexural tension. Elastic, plastic, and fracture behavior. ASTM, RILEM, and USBR. Cyclic loading. Microstructures of concrete. Size effects. Letter grading. Mr. Ju (W)

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

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

135C. Finite Element Methods. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 130, 135B. Direct approach for truss analysis, strong form and weak form, approximation functions for finite element methods, weighted residual methods, Ritz method, variational method, convergence criteria and rate of convergence, natural coordinates and shape functions, isoparametric finite elements, finite element formulation of multidimensional heat flow and elasticity, numerical integration and approximation properties, finite element formulation of beam. Letter grading. Mr. Chen, Mr. Ju (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, instrumentation, and test of a 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 (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. Letter grading. Mr. Ju (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibration of 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 (F)

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

142. Design of Reinforced Concrete Structures. (4) Lecture, three hours; discussion, three hours; outside study, six hours. Requisite: course 135A. Beams, columns, and slabs in reinforced concrete structures. Properties of reinforced concrete materials. Design of beams and slabs for flexure, shear, anchorage of reinforcement, and deflection. Design of columns for axial force, bending, and shear. Ultimate strength design methods. Letter grading. Mr. Wallace (W)

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, six hours. Requisites: courses 135A, 142. Prestressing and post-tensioning techniques. Properties of concrete and prestressing steels. Design considerations: anchorage/bonding of cables/wire, flexure analysis by superposition and strength methods, draping of cables, deflection and stiffness, indeterminate structures, limitation of prestressing. Letter grading. Mr. Wallace (Sp)

144. Structural Systems Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 137, 141, 142. Design course for civil engineering students, with focus on design and performance of complete building structural systems. Uniform Building Code dead, live, wind, and earthquake loads. Design of concrete masonry building. Computer analysis of performance of designed building. Letter grading. Mr. Wallace (Sp)

147. Design and Construction of Tall Buildings. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 135B, 141. Limited enrollment. Introduction to total design process and professional participants. Systematic presentation of advantages and limitations of different structural forms and systems. Identification of critical design factors influenced by tallness. Foundation systems. Construction site visits, costing, and scheduling. Letter grading. Mr. Wallace (W)

150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Mechanical and Aerospace Engineering 103. Precipitation, evaporation and plant transpiration, infiltration and recharge, climatology, stream flow analysis, flood frequency analysis, groundwater, snow hydrology, hydrologic simulation. Letter grading. Mr. Margulis (F)

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. 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 analysis and design applied to water resources engineering. Letter grading. Ms. Hogue (W)

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

154. Chemical Fate and Transport in Aquatic Environments. (4) Lecture, four hours; outside study, eight hours. Requisites: Chemistry 20A, 20B, Mathematics 31A, 31B, Physics 1A, 1B. 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 chemistry, chemical sorption, biodegradation, and bioaccumulation. Practical quantitative problems solved considering both reaction and transport of chemicals in environment. Letter grading. Ms. Jay (F)

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 modify water quality. Fundamentals of phenomena governing design of engineered systems for water and wastewater treatment systems. Field trip. Letter grading. Mr. Stenstrom (F)

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

156B. Water Quality Control Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: course 156A, Chemistry 20A, 20B. Characterization and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include solids, nitrogen species, oxygen demand, chlorine, alkalinity, hardness, and trace analysis. Discussion of relevance of these measurements to water resource engineering. Letter grading. Mr. Stenstrom (W)

157B. Design of Water Treatment Plants. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; other, four hours. Requisite: course 155. Water quality standards and regulations, overview of water treatment plants, design of unit operations, predesign of water treatment plants, hydraulics of plants, process control, and cost estimation. Letter grading. Mr. Stenstrom (Sp)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Requisite: course 155. Process design of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and economics. Letter grading. Mr. Stenstrom (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, evaporation, infiltration, and runoff. Use of hydrologic variables and parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Field trip required. Letter grading. Ms. Hogue (W,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 concentrations/standards, urban and regional ozone, aerosol pollution, formation/deposition of acid precipitation, fate of anthropogenic/toxic/natural organic and inorganic compounds, selected global chemical cycle(s). Control technologies. Letter grading. Mr. Stolzenbach (Sp)

164. Hazardous Waste Site Investigation and Remediation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150, 153, Mechanical and Aerospace Engineering 103. Overview of hazardous waste types and potential sources. Techniques in measuring and modeling subsurface flow and contaminant transport in the subsurface. Design project illustrating a remedial investigation and feasibility study. Letter grading. Ms. Jay (W)

M166. Environmental Microbiology. (4) (Formerly numbered 166.) (Same as Environmental Health Sciences M166.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 153. Microbial cell and its metabolic capabilities, microbial genetics and its potentials, growth of microbes and kinetics of growth, microbial ecology and diversity, microbiology of wastewater treatment, probing of microbes, public health microbiology, pathogen control. Letter grading. Ms. Jay (F)

166L. Environmental Microbiology and Biotechnology Laboratory. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; outside study, four hours. Requisite: course M166. General laboratory practice within environmental microbiology, sampling of environmental samples, classical and modern molecular techniques for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples, laboratory setups for studying environmental biotechnology. Letter grading. Ms. Jay (Sp)

180. Introduction to Transportation Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/seniors. General characteristics of transportation systems, including streets and highways, rail, transit, air, and water. Capacity considerations including time-space diagrams and queueing. Components of transportation system design, including horizontal and vertical alignment, cross sections, earthwork, drainage, and pavements. Letter grading. Mr. Stewart (Sp)

188. Special Courses in Civil and Environmental Engineering. (4) (Formerly numbered 198.) Lecture, four hours; outside study, eight hours. Special topics in civil engineering for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (F,W,Sp)

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

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

Graduate Courses

220. Advanced Soil Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. State of stress. Consolidation and settlement analysis. Shear strength of granular and cohesive soils. In situ and laboratory methods for soil property evaluation. Letter grading. Mr. Stewart (F)

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

222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Review of engineering problems involving soil dynamics. Fundamentals of theoretical soil dynamics: response of sliding block-on-a-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. Vucetic (W)

223. Earth Retaining Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 121. Basic concepts of theory of earth pressures behind retaining structures, with special application to design of retaining walls, bulkheads, sheet piles, and excavation bracing. Effects of flexibility, creep in soils, and construction techniques on stability of bulkheads and sheet piles. Mechanical stabilization of soils, such as with soil nails and geosynthetics. Letter grading. Mr. Vucetic (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 static and cyclic soil behavior. Cyclic degradation and liquefaction of saturated soils. Cyclic settlement of partially saturated and dry soils. Concept of volumetric cyclic threshold shear strain. Factors affecting shear moduli and damping during cyclic loading. Postcyclic behavior under monotonic loads. Critical review of laboratory, field, and modeling testing techniques. Letter grading. Mr. Vucetic (F)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 137. Analysis of earthquake ground motions, including seismic source modeling, travel path effects, and site response effects. Probabilistic seismic hazard analysis. Soil liquefaction. Seismic slope stability. 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, geosynthetics, solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of 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, nonexistence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

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

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

M230B. Elasticity. (4) (Formerly numbered M230.) (Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course M230A. Solution of linear elastostatic problems using special techniques. Field equations of linear elastostatics; uniqueness of solution; Betti/Rayleigh reciprocity relation; solution of two-dimensional problems using stress functions; stress concentration at holes and inclusions; complex variables and transform methods in elasticity; stress singularity at cracks and corners; stresses and strains in composites; three-dimensional problems — Kelvin, Boussinesq, and Cerruti problems, boundary integral equation method. Letter grading. Mr. Ju, Mr. Mal (W)

232. Theory of Plates and Shells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or Mechanical and Aerospace Engineering 156B. Small and large deformation theories of thin plates; energy methods; free vibrations; membrane theory of shells; axisymmetric deformations of cylindrical and spherical shells, including bending. Letter grading. Mr. Ju (F)

233. Mechanics of Composite Material Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M230B, 232. Elastic, anisotropic stress-strain-temperature relations. Analysis of prismatic beams by three-dimensional elasticity. Analysis of laminated anisotropic plates and shells based on classical and first-order shear deformation theories. Elastodynamic behavior of laminated plates and cylinders. Letter grading. Mr. Ju (Sp)

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

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

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

236. Stability of Structures I. (4) Lecture, four hours; outside study, eight hours. Requisite: 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)

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

238. Computational Solid Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 235B. Advanced finite element and meshfree methods for computational solid mechanics. Stability and consistency in temporal discretization of parabolic and hyperbolic systems. Analysis of numerical dissipation and dispersion. Multifield variational principles for constrained problems. Meshfree methods: approximation theories, Galerkin meshfree methods, collocation meshfree methods, imposition of boundary conditions, domain integration, stability. Letter grading. Mr. Chen (Sp)

M239. Plasticity. (4) (Same as Mechanical and Aerospace Engineering M256C.) Lecture, four hours; outside study, eight hours. Requisites: Mechanical and Aerospace Engineering 256A, M256B. Classical rate-independent plasticity theory, yield functions, flow rules and thermodynamics. Classical rate-dependent viscoplasticity, Perzyna and Duvant/Lions types of viscoplasticity. Thermoplasticity and creep. Return mapping algorithms for plasticity and viscoplasticity. Finite element implementations. Letter grading. Mr. Ju, Mr. Mal (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)

242. Advanced Reinforced Concrete Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 142. Design of building and other structural systems for vertical and lateral loads. Earthquake forces. Ductility in elements and systems. Columns: secondary effects and biaxial bending. Slabs: code and analysis methods. Footings, shear walls, diaphragms, chords, and collectors. Detailing for ductile behavior. Retrofitting. Letter grading. Mr. Wallace (W)

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 construction. Letter grading. Mr. Wallace (W)

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

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

247. Advanced Structural Dynamics for Civil Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 137, 235A, 235B, M237A or 246. Dynamic response of linear structures with proportional and nonproportional damping using modal superposition methods. Dynamic response of inelastic systems using numerical integration. Introduction to base isolation and active structural control. Earthquake engineering applications. Letter grading. Mr. Ju (Sp)

248. Probabilistic Structural Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 244, Electrical Engineering 131A, Mechanical and Aerospace Engineering 174. Introduction to probability theory and random processes. Dynamic analysis of linear and nonlinear structural systems subjected to stationary and nonstationary random excitations. Reliability studies related to first excursion and fatigue failures. Applications in earthquake, offshore, wind, and aerospace engineering. Letter grading. Mr. Ju (Sp)

249. Selected Topics in Structural Engineering and Mechanics. (2) Lecture, two hours; outside study, six hours. Review of recent research and developments in structural engineering and mechanics. Structural analysis, finite elements, structural stability, dynamics of structures, structural design, earthquake engineering, ground motion, elasticity, plasticity, structural mechanics, mechanics of composites, and constitutive modeling. May be repeated for credit. S/U grading. Mr. Ju, 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 interrelationship of major topics such as rainfall and evaporation, soils and infiltration properties, runoff and snowmelt processes. Introduction to rainfall-runoff modeling, floods, and policy issues involved in water resource engineering and management. Letter grading. Mr. Margulis (F)

250B. Groundwater Hydrology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150. Theory of movement and occurrence of water in subterranean aquifers. Steady flow in confined and unconfined aquifers. Mechanics of wells; steady and unsteady radial flows in confined and unconfined aquifers. Theory of leaky aquifers. Parameter estimation. Seawater intrusion. Numerical methods. Applications. Letter grading. Mr. Yeh (W)

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

250D. Water Resources Systems Engineering. (4) (Formerly numbered 251.) 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 multiobjective 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 250A, 251C. Introduction to hydrologic modeling concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis, and application of models for flood forecasting and prediction of streamflows in water resource applications. Letter grading. Ms. Hogue (Sp)

251B. Land Surface Remote Sensing and Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250A. Introduction to basic concepts of remote sensing, how these measurements are related to hydrologically relevant parameters like topography, soil moisture, snow properties, vegetation, and precipitation, and introduction to basic concepts of estimation theory (weighted least squares, maximum likelihood, Bayesian estimation) for purposes of hydrologic data assimilation. Letter grading. Mr. Margulis (Sp)

251C. Mathematical Modeling of Contaminant Transport in Groundwater. (4) (Formerly numbered 250C.) Lecture, four hours; laboratory, 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, coupled and multiphase pollution problems, computer programs and applications. Letter grading. Mr. Yeh (W)

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

253. Mathematical Models for Water Quality Management. (4) Lecture, four hours; outside study, eight hours. Requisite: course 153. Development of mathematical models for simulating environmental engineering problems. Emphasis on numerical techniques to solve nonlinear partial differential equations and their application to environmental engineering problems. Letter grading. Mr. Stenstrom (F)

254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture, four hours; outside study, eight hours. Requisites: Chemistry 20B, Mathematics 31A, 31B, Physics 1A, 1B. Equilibrium and kinetic descriptions of chemical behavior of metals and inorganic ions in natural fresh/marine surface waters and in water treatment. Processes include acid-base chemistry and alkalinity (carbonate system), complexation, precipitation/dissolution, absorption oxidation/reduction, and photochemistry. Letter grading. Mr. Stenstrom (F)

255A. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 254A. Review of momentum and mass transfer, chemical reaction engineering, coagulation and flocculation, granular filtrations, sedimentation, carbon adsorption, gas transfer, disinfection, oxidation, and membrane processes. Letter grading. Mr. Stenstrom (W)

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

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 disposal, and ultrapure water systems. Discussion 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) 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 a maximum of 4 units. Letter grading. Mr. Stenstrom (F,W,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 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 (F)

M262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M203A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, thermochemistry, spectroscopy, and photochemistry; chemical composition and history of Earth's atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and climate. S/U or letter grading. (W)

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 (for majors with consent of instructor after successful completion of written and oral comprehensive examination and for nonmajors at discretion of major department) 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 263A. 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 models 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, eight hours. Designed for graduate environmental engineering program students. Physical chemistry and mass transfer fundamentals related to contaminant fate and transport in soil, air, and water systems, including soil/water sorption and desorption, contaminant retardation, vaporization and dissolution of nonaqueous phase liquids (NAPL), and other environmental systems. 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)

266. Environmental Biotechnology. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 153, 254A. Environmental biotechnology — concept and potential, biotechnology of pollutional control, bioremediation, biomass conversion: composting, biogas and bioethanol production. Letter grading. Ms. Jay (Sp)

296. 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)

297. Seminar: Current Topics in Civil Engineering. (2 to 4) Seminar, to be arranged. Lectures, discussions, and student presentations and projects in areas of current interest in civil engineering. May be repeated for credit. S/U grading. (F,W,Sp)

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

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

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

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

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

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

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

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

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

Computer Science

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Professors

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Joseph J. DiStefano III, Ph.D.
Michael G. Dyer, Ph.D.
Milos D. Ercegovac, Ph.D.
Deborah L. Estrin, Ph.D. *(Jonathan B. Postel Professor of Networking)*
Mario Gerla, Ph.D.
Sheila A. Greibach, Ph.D.
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Lixia Zhang, Ph.D.

Professors Emeriti

Algirdas A. Avizienis, Ph.D.
Bertram Bussell, Ph.D.
Jack W. Carlyle, Ph.D.
Gerald Estrin, Ph.D.
Thelma Estrin, Ph.D.
Leonard Kleinrock, Ph.D.
Allen Klinger, Ph.D.
Lawrence P. McNamee, Ph.D.
Michel A. Melkanoff, Ph.D.
Judea Pearl, Ph.D.
Jacques J. Vidal, Ph.D.

Associate Professors

Adnan Y. Darwiche, Ph.D.
Eliezer M. Gafni, Ph.D.
Songwu Lu, Ph.D.
David A. Rennels, Ph.D.
Stefano Soatto, Ph.D.
Yuval Tamir, Ph.D.
Song-Chung Zhu, Ph.D.

Assistant Professors

Junghoo (John) Cho, Ph.D.
Petros Faloutsos, Ph.D.
Edward Kohler, Ph.D.
Rupak Majumdar, Ph.D.
Todd Millstein, Ph.D.
Glenn Reinman, Ph.D.

Senior Lecturer

Leon Levine, M.S., *Emeritus*

Lecturers P.S.O.E.

Paul Eggert, Ph.D.
David Smallberg, M.S.

Adjunct Professors

Alan Kay, Ph.D.
Boris Kogan, Ph.D.
Gerald J. Popek, Ph.D.
Mohammad "Medy" Sanadidi, Ph.D.

Adjunct Associate Professors

Leon Alkalai, Ph.D.
Peter L. Reiher, Ph.D.

Scope

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 systems, information and data management, artificial intelligence, computer science theory, 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 laboratories specializing in areas such as distributed systems, multimedia computer communications, distributed sensor networks, VLSI systems, VLSI CAD, embedded and reconfigurable systems, computer graphics, 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).

Undergraduate Program Objectives

The goals and objectives of the Computer Science and Computer Science and Engineering majors are to train the next generation of computer scientists and engineers with

1. The broad scientific and technical skills needed for initial employment and a productive career in a rapidly changing environment to provide (a) a thorough grounding in mathematics and science as a foundation for an understanding of computer science, engineering, and many of the technical applications to which computers are applied, (b) a common core knowledge of the principal areas of computer science (theory, algorithms, data structures, software design, concepts of programming languages, and computer architecture) and an understanding of the fundamentals of one engineering or computer applications discipline, (c) the ability to formulate and solve computer science and engineering problems, including design and analysis, conducting measurements, and evaluating trade-offs of functionality and cost, (d) outstanding skills in programming and good engineering practices of software development, and (e) the ability to use modern design and analysis tools for implementing and evaluating hardware, software, and engineering designs
2. Specialization in preparation for research or engineering practice in computing and the fertile application areas where computing and other technical fields intersect to (a) provide understanding of specialized areas of computer science and in engineering as preparation for research or cross-disciplinary engineering, (b) provide the ability to understand the larger systems goals with the ability to design specifications and integrate separately engineered products into a well-balanced design that meets user needs, and (c) take maximum advantage of the resources of a research university through undergraduate involvement in research with mentoring by faculty researchers and their research associates
3. Professional skills needed for success in teamwork, written and oral communications, an understanding of the societal, economic, and ethical implications of their work, and familiarity with rapidly changing technologies and the necessity for lifelong learning to remain relevant by (a) providing ample individual projects for students to develop and demonstrate knowledge gained, creativity, and written and oral communication skills, (b) providing opportunities for students to develop and demonstrate teamwork, written and oral communications, and to integrate knowledge and skills gained from preceding studies through capstone design courses in computer hardware and/or software, (c) providing coverage of ethical and societal issues through discussions in regular courses and a required specialized ethics course, (d) providing familiarity with advanced developments in technology-based courses and a sufficient understanding of the history and technology advances in each area to demonstrate the need for lifelong learning, (e) developing independent study skills to obtain and demonstrate knowledge of state-of-the-art information, and (f) providing an environment that nurtures student involvement and leadership skills by actively supporting student organizations and their projects
4. A grounding in humanities and social sciences to broaden student perspective by better understanding student culture and the relationship between engineering and science and other forms of creative thinking, and by developing lifelong interests in nontechnical areas to provide an appreciation of creative thinking of a nonquantitative nature found in the arts and humanities, and a better understanding of the wider culture in which scientists and engineers function most effectively both as citizens and professionals

Computer Science and Engineering B.S.

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 pre-

Poster session at the Computer Science department research review.

pared for employment in a wide spectrum of high-technology industries.

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

The Major

Course requirements are as follows (186 minimum units required):

1. Four core courses: Computer Science 31, 32, 33, M51A (or Electrical Engineering M16)
2. Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), 180, 181, Electrical Engineering 10, 102, 103, 110, 110L, 115A, 115AL, 115C, Statistics 110A; 6 laboratory units from Computer Science M152A (or Electrical Engineering M116L) and M152B (or Electrical Engineering M116D)
3. Five upper division elective courses from the Computer Science Department (one elective may be from the Electrical Engineering Department, excluding Electrical Engineering 100). Course 199 may normally be taken only as excess units; however, students may petition for exceptions in extraordinary situations
4. Chemistry and Biochemistry 20A; Electrical Engineering 1, 2, Physics 1A, 1B, 4AL, 4BL; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Computer Science B.S.

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.

The Major

Course requirements are as follows (182 minimum units required):

1. Four core courses: Computer Science 31, 32, 33, M51A (or Electrical Engineering M16)
2. Computer Science 111, 112, 118, 131, 132, M151B (or Electrical Engineering M116C), 161, 180, 181, Statistics 110A; Computer Science 170A or Electrical Engineering 103; 6 laboratory units from Computer Science M152A (or Electrical Engineering M116L) and M152B (or Electrical Engineering M116D). Students who select Electrical Engineering 103 may not receive credit for Mathematics 151A under the technical minor
3. Five elective upper division computer science courses
4. A minor or technical support area composed of three upper division courses selected from one of the following areas: astronomy, atmospheric and oceanic sciences, biology, chemical and biomolecular engineering, chemistry and biochemistry, civil and environmental engineering, Earth and space sciences, economics, electrical engineering, information studies, linguistics, management, materials science and engineering, mathematics, mechanical and aerospace engineering, molecular biology, physics
5. Electrical Engineering 1, 2, Physics 1A, 1B, 4AL, 4BL; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61
6. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the "Publications" link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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 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 M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 105D, 199.

Breadth Requirement. Candidates for the M.S. in Computer Science must satisfy the computer science breadth requirement by the end of the fourth quarter in graduate residence at UCLA. The requirement is satisfied by mastering the contents of six undergraduate courses in computer science chosen from the following two groups:

Group I: Four required courses or equivalent from Computer Science M51A, 143 or 180, M151B, 181.

Group II: Two required courses or equivalent from Computer Science 111, 112 or 118, 131 or 132, 161, 170A or 174A.

In addition, for each degree students must complete at least one course per quarter for three quarters of Computer Science 201 with grades of Satisfactory.

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

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, and three may be in the 100 or 200 series. The remaining two courses must be 598 courses involving work on the thesis.

Comprehensive Examination Plan

Consult the department.

Thesis Plan

The thesis is a report on the results of the 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 narrow scope, the thesis must show significant style, organization, and depth of understanding of the subject. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

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

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

Computer Science Ph.D.

Major Fields or Subdisciplines

Artificial intelligence; computational systems biology (formerly biomedical systems/computational biology); computer networks; computer science theory; computer system architecture; information and data management; software systems.

Course Requirements

The basic program of study for the Ph.D. degree is built around one major field and two minor fields; the major and at least one minor must be in computer science. The major field corresponds to a body of knowledge contained in six courses, at least four of which are graduate courses.

Breadth Requirement. Candidates for the Ph.D. in Computer Science must satisfy the computer science breadth requirement by the end of the fourth quarter in graduate residence at UCLA. The requirement is satisfied by mastering the contents of six undergraduate courses in computer science chosen from the following two groups:

Group I: Four required courses or equivalent from Computer Science M51A, 143 or 180, M151B, 181.

Group II: Two required courses or equivalent from Computer Science 111, 112 or 118, 131 or 132, 161, 170A or 174A.

In addition, for each degree students must complete at least one course per quarter for three quarters of Computer Science 201 with grades of Satisfactory.

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

After mastering the body of knowledge defined in the three fields and passing the breadth requirement, students take a written qualifying examination. After passing the written qualifying examination, students should form a doctoral committee and prepare 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 student's preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are "inside" members and must hold appointments at UCLA in the student's major department in HSSEAS. The "outside" member must be a UCLA faculty member outside the student's major department.

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

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

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

Computational Systems Biology

This field can be selected as a major or minor field for the Ph.D. in Computer Science.

Subject Matter and Course Offerings

Emphasis is on integrative computational and mathematical modeling methodologies, algorithms, and quantitative methods for life sciences applications, both basic and applied. Integrative here puts the focus on biological (or medical) systems (systems biology), that is, computational mathematical modeling and simulation approaches to biological systems. Research topics typically involve one or more of the following areas:

1. Integrated computational and biological approaches to organismic, cellular, and mechanism-level studies of biological, including biomedical, systems. Particular emphasis on dynamic systems modeling and simulation of cancer and other disease processes: neural, neuroendocrine, immune, and metabolic systems
2. Pharmacokinetics (PK), pharmacodynamics (PD), and physiologically-based PK modeling (PBPK)
3. Optimization of clinical therapy models
4. Modeling methodology for life science research, including experiment design simulation and optimization
5. Software development for modeling and model selection, and for kinetic analysis of biological systems, with emphasis on expert systems, user-friendly interfaces and universally available world wide web based software systems
6. Integrated modeling and experimental research in physiology, pharmacology, biochemistry, genomics, bioinformatics and related fields, developing the interface between (theoretical) modeling and laboratory experimentation and data analysis
7. Computational cardiology
8. Genomics, proteomics, metabolomics, and microarray data modeling

Computer Networks

The computer networks field involves the study of computer systems, computer communications, computer networks, local area networks, high-speed networks, distributed algorithms, and distributed systems, emphasizing the ability to evaluate system performance at all levels of activity (but principally from the systems viewpoint) and to identify the key parameters of global system behavior. Of interest are mathematical models that lend themselves to analysis and that can be used to predict the system throughput, response time, utilization of devices, flow of jobs and messages, bottlenecks, speedup, power, etc. In addition, computer networks are constructed using design methodologies subject to appropriate cost and objective functions. The field provides the techniques for system performance, evaluation, and design.

The tools required to carry this out include probability theory, queueing theory, queueing networks, graph and network flow theory, mathematical programming, optimization theory, operating systems design, computer communication methods and protocols, simulation methods, measurement tools and methods, and heuristic design procedures. The outcome of these studies is to provide the following:

1. An appropriate model of the computer system under study
2. An adequate (exact or approximate) analysis of the behavior of this 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. A design methodology

Resource Allocation

Many of the issues involved in the consideration of computer networks deal with the allocation of resources among competing demands. 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. The use of demand allocation is found to be effective, since it takes advantage of statistical averaging

AREAS INCLUDED IN THE COMPUTER NETWORKS FIELD

Typical Systems Studied		Tools Used
• Computer networks	• Local-area networks	• Probability theory
• Packet switching	• Communication processors	• Queueing theory
• Multiprogramming systems	• High-speed networks	• Queueing networks
• Parallel processing systems	• Photonic networks	• Graph theory
• High-performance computers	• Neural networks	• Network flow theory
• Distributed processing systems	• Communication protocols	• Optimization theory
• Time-shared systems	• Network control procedures (centralized and distributed)	• Mathematical programming
• Satellite and ground radio packet switching systems	• Mobile networks	• Heuristic design algorithms
• Cellular radio systems		• Simulation
• Personal communication networks		• Distributed algorithms
		• Measurement
		• Information theory
		• Control theory

effects. We identify and exploit this averaging effect whenever possible in our system modeling, analysis, and design. This demand multiplexing (sharing of large systems) comes in many forms and is known by names such as asynchronous time division multiplexing, line switching, message switching, store and forward systems, packet switching, frame relay, call switching, 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

1. The study of the structure and behavior of computer systems
2. The development of new algorithms and computing structures to be implemented in hardware, firmware, and software
3. The development of tools to enable system designers to describe, model, fabricate, and test highly complex computer systems

Computer systems are among the most complex systems ever developed and as such are the subject of intensive study. The computer architect must be able to define the functions to be provided by a computing system and the way in which they are implemented. Due to their complexity, computer systems must be decomposed into subsystems. This decomposition is carried out at several levels until the desired system can be composed from well-understood reusable hardware and software elements. One way to categorize these subsystems is by processor, memory, data transmission and interconnection, control, input/output, and operating system elements. The subsystems must be precisely specified and their interactions modeled and thoroughly understood before a system can be fabricated.

Emphasis of Computer Science Theory

- Design and analysis of algorithms
- Distributed and parallel algorithms
- Models for parallel and concurrent computation
- Online and randomized algorithms
- Computational complexity
- Automata and formal languages
- Cryptography and interactive proofs

Properties of a well-engineered system include ease and efficiency of programming and behavior that is predictable to a user. Moreover, a well-engineered system is one that satisfies cost, performance, and reliability constraints.

A comprehensive set of courses is offered in the areas of advanced computer architecture, arithmetic processor systems, fault-tolerant systems, memory systems, operating systems, data communications, VLSI-based architectures, computer-aided design of VLSI circuits and systems, distributed computing, and parallel processing. The courses are intended to prepare students for advanced engineering and continuing research. Advanced courses are also offered to introduce students to research areas being pursued by the faculty.

The computer architecture field at UCLA offers strong emphasis on systems issues of design, performance modeling, and algorithms. Some of the areas of current interest are described below:

1. *Fault-tolerant computing* involves the design of systems that can continue operation in the presence of faults. This includes errors in specification, operator errors, software faults, and random failures of hardware components. Design techniques and modeling tools are being studied for several levels of system design, including specification, software fault-tolerance, and fault-tolerance techniques for VLSI.
2. *Novel architectures* encompass the study of computations which 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.

3. 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.
4. The study of *computational algorithms and structures* deals with the relationship between computational algorithms and the physical structures which 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.
5. *Computer-aided design of VLSI circuits* is an active research area which develops techniques for the automated synthesis of large-scale systems. Topics include logic synthesis, physical design, testing, and yield enhancement for various VLSI technologies such as standard cells, gate arrays, field programmable gate arrays (FPGAs), and multichip modules (MCMs). Other areas of study include a structural theory of the large-scale global optimizations which arise in VLSI CAD.
6. *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. In addition to detailed studies of these issues there is an active program in the design of MOS large-scale integrated circuits.

Information and Data Management

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

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

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

Software Systems

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

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

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

Facilities

Departmental laboratory facilities for instruction and research include:

Artificial Intelligence Laboratories

Artificial Intelligence Laboratory. For investigating knowledge representation systems, pattern recognition, expert systems, intelligent user agents, planning, problem solving, heuristic search, and related areas

Cognitive Systems Laboratory. 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. For investigating methods for effective computer support of small teams involved in design and research

UCLA Vision Laboratory. 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

Computational System Biology Laboratories

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. 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. 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. 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/

MAGIX: Modeling Animation and Graphics Laboratory. For research on computer graphics, physics-based animation, robotics, and biomechanics. See http://www.magix.ucla.edu

Computer Networks Laboratories

CENS Systems Laboratory. 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. For investigating local-area networks, packet-switching networks, and packet-radio networks

High-Performance Internet Laboratory. 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/hpi/

Internet Research Laboratory. For exploring the forefront of current Internet architecture and protocol development, including fault tolerance in large-scale distributed systems such as the Internet routing infrastructure, Internet distance measurement, scalable IP multicast delivery in absence of network multicast support, distributed Internet information discovery, and protocol design principles for large-scale self-organizing systems and their applications to sensor networking. See http://irl.cs.ucla.edu

Wireless Adaptive Mobility Laboratory. For investigating wireless local-area networks and the interaction between 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). Promotes all aspects of research and education in cryptography and computer security. See http://www.cs.ucla.edu/security/

Theory Laboratory. 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. For investigating the design, implementation, and evaluation of computer systems that use state-of-the-art technology to achieve both high performance and high reliability. Research is often related to multiprocessors and multicomputers in the context of general-purpose as well as embedded systems. See http://www.cs.ucla.edu/csd/research/labs/csl/

Digital Arithmetic and Reconfigurable Architecture Laboratory. 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. 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. 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), and system-in-a-package (SIPs). See http://ballade.cs.ucla.edu

Information and Data Management Laboratories

Data Mining Laboratory. 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. 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://kme-www.cs.ucla.edu

Multimedia Stream System Laboratory. For investigation and development of stream-based data model constructs and the corresponding querying facilities in response to the growing requirements of advanced multimedia database applications. See http://www.mmss.cs.ucla.edu

Multimedia Systems Laboratory. 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. 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. For research into compilers, embedded systems, and programming languages

Distributed Simulation Laboratory. For research on operating system support and applications and utilization of special architectures such as the Intel Hypercube

Laboratory for Advanced System Research. For developing advanced operating systems, distributed systems, and middleware and conducting research in systems security

Parallel Computing Laboratory. 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. 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 or school network (SEASnet).

The departmental research network includes at least 30 Sun Sparcstation 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 600, the majority running the UNIX operating system. The network consists of switched10/100 ethernet to the desktop with a gigabit backbone connection. The department LAN is connected to the campus ATM backbone. A Lucent 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 Academic 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

Rajive L. Bagrodia, Ph.D. (U. Texas, 1987)
Wireless networks, nomadic computing, parallel programming, performance evaluation of computer and communication systems

Alfonso F. Cardenas, Ph.D. (UCLA, 1969)
Database management, distributed heterogeneous and multimedia (text, image/picture, video, voice) systems, information systems planning and development methodologies, software engineering, medical informatics, legal and intellectual property issues

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

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

*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

Mario Gerla, Ph.D. (UCLA, 1973)
Analysis, design, and control of computer communications networks and systems, computer network protocol evaluation, queueing networks, topological design and routing problems in large networks, design and evaluation of algorithms for distributed computation

Sheila A. Greibach, Ph.D. (Harvard, 1963)
Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability

Richard E. Korf, Ph.D. (Carnegie Mellon, 1983)
Problem solving, heuristic search, planning in artificial intelligence

Richard R. Muntz, Ph.D. (Princeton, 1969)
Multimedia systems, database systems, data mining

Rafail Ostrovsky, Ph.D. (MIT, 1992)
Theoretical computer science, cryptography, complexity theory, randomization, network protocols, geometric algorithms, data mining

Jens Palsberg, Ph.D. (Aarhus U., Denmark, 1992)
Compilers, embedded systems, programming languages

D. Stott Parker, Jr., Ph.D. (Illinois, 1978)
Data mining, information modeling, scientific computing, bioinformatics, database and knowledge-based systems

Miodrag Potkonjak, Ph.D. (UC Berkeley, 1991)
Computer-aided analysis and synthesis of system level designs, behavioral synthesis, and interaction between high-performance application-specific computations and communications

Majid Sarrafzadeh, Ph.D. (Illinois, 1987)
Computer engineering, embedded systems, VLSI CAD, algorithms

Carlo Zaniolo, Ph.D. (UCLA, 1976)
Knowledge bases and deductive databases, parallel execution of PROLOG programs, formal software specifications, distributed systems, artificial intelligence, and computational biology

Lixia Zhang, Ph.D. (MIT, 1989)
Computer network, data networking, network architectures and protocols

Professors Emeriti

Algirdas A. Avizienis, Ph.D. (Illinois, 1960)
Digital computer architecture and design, fault-tolerant computing, digital arithmetic

Bertram Bussell, 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

Gerald Estrin, Ph.D. (Wisconsin, 1951)
Computer systems architecture, methodology and supporting tools for design of concurrent systems, automating design teamwork, restructurable architectures

Thelma Estrin, Ph.D. (Wisconsin, 1951)
Biomedical engineering, application of technology and computers to health care, computer methods in neuroscience, engineering education

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

* Also Professor of Medicine

computing, nomadic computing, and distributed and parallel processing systems

Allen Klinger, Ph.D. (UC Berkeley, 1966)
Pattern recognition, picture processing, biomedical applications, mathematical modeling

Lawrence P. McNamee, Ph.D. (Pittsburgh, 1964)
Computer graphics, discrete simulation, digital filtering, computer-aided design, LSI fabrication techniques, printed circuit board design

Michel A. Melkanoff, Ph.D. (UCLA, 1955)
Programming languages, data structures, database design, relational models, simulation systems, robotics, computer-aided design and manufacturing, numerical-controlled machinery

Judea Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1965)
Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference, causal and counterfactual analysis

*Jacques J. Vidal, Ph.D. (U. Paris, Sorbonne, 1961)
Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems/signal processing

Associate Professors

Adnan Y. Darwiche, Ph.D. (Stanford, 1993)
Knowledge representation and automated reasoning (symbolic and probabilistic), applications to diagnosis, prediction, planning, and verification

Eliezer M. Gafni, Ph.D. (MIT, 1982)
Computer communication, networks, mathematical programming algorithms

Songwu Lu, Ph.D. (Illinois, 1999)
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

David A. Rennels, Ph.D. (UCLA, 1973)
Digital computer architecture and design, fault-tolerant computing, digital arithmetic

Stefano Soatto, Ph.D. (Cal Tech, 1996)
Computer vision, autonomous systems

Yuval Tamir, Ph.D. (UC Berkeley, 1985)
Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection networks and switches, CPU and memory system architectures, reconfigurable systems

Song-Chun Zhu, Ph.D. (Harvard, 1996)
Computer vision, statistical modeling and computing, vision and visual arts

Assistant Professors

Junghoo (John) Cho, Ph.D. (Stanford, 2002)
Databases, web technologies, information discovery and integration

Petros Faloutsos, Ph.D. (Toronto, 2001)
Computer graphics, computer animation

Edward Kohler, Ph.D. (MIT, 2001)
Operating systems, software systems, programming languages and systems, networking systems

Rupak Majumdar, Ph.D. (UC Berkeley, 2003)
Computer-aided verification

Todd Millstein, Ph.D. (U. Washington, 2003)
Programming languages

Glenn Reinman, Ph.D. (UC San Diego, 2001)
Computer architecture

Senior Lecturer

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

Lecturers P.S.O.E.

Paul Eggert, Ph.D. (UCLA, 1980)
Programming languages, operating systems principles, compilers, Internet

David Smallberg, M.S. (UCLA, 1998)
Programming languages, software development

Adjunct Professors

Alan Kay, Ph.D. (Utah, 1969)
Smalltalk programming language, object-oriented programming, GUI, computers and technology in general

Boris Kogan, Ph.D. (Moscow, Russia, 1962)
Application of multiprocessor systems with massive parallelism to simulation of dynamic phenomena in excitable biological tissues

Gerald J. Popek, Ph.D. (Harvard, 1973)
Privacy and security in information systems, operating system software design, representation for design and evaluation of databases

Mohammad "Medy" Sanadidi, Ph.D. (UCLA, 1982)
Computer networking, path characteristics estimation and applications in flow control, adaptive streaming and overlays design, probability models of computing systems, algorithms and networks

Adjunct Associate Professors

Leon Alkalai, Ph.D. (UCLA, 1989)
Computer architecture

Peter L. Reiher, Ph.D. (UCLA, 1987)
Computer and network security, ubiquitous computing, file systems, distributed systems

Lower Division Courses

1. Freshman Computer Science Seminar. (2) Seminar, two hours. 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. Rennels (F)

2. Great Ideas in Computer Science. (4) Lecture, four hours; outside study, eight hours. Broad coverage for liberal arts and social sciences students of computer science theory, technology, and implications, including artificial and neural machine intelligence, computability limits, virtual reality, cellular automata, artificial life, programming languages survey, and philosophical and societal implications. P/NP or letter grading. Mr. Dyer (Sp)

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

31. Introduction to Computer Science I. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Limited to Computer Science and Electrical Engineering majors. 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. Abstract data types, object-oriented programming. Examples and exercises from computer science theory and applications. Letter grading.
Mr. Palsberg, Mr. Smallberg (F,W)

32. Introduction to Computer Science II. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 31. Limited to Computer Science and Electrical Engineering majors. Object-oriented software development. Abstract data type definition and use. Overloading, inheritance, polymorphism. Object-oriented view of data structures: stacks, queues, lists. Algorithm analysis. Trees, graphs, and associated algorithms. Searching and sorting. Case studies and exercises from computer science applications. Letter grading.
Mr. Palsberg, Mr. Smallberg (W,Sp)

33. Introduction to Computer Organization. (5) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced requisite: course 32. Limited to Computer Science and Electrical Engineering majors. 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)

35. Software Construction Fundamentals. (2) Lecture, two hours; laboratory, one hour; outside study, three hours. Requisites: courses 31, 32. Fundamentals of commonly used software tools and environments, particularly open-source tools to be used in upper division computer science courses. Brief survey of related areas of active research and development. Letter grading. Mr. Eggert (F)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical Engineering M16.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Physics 1C. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.
Mr. Ercegovac, Mr. Potkonjak (F,W,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 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

111. Operating Systems Principles. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 32, 33. Introduction to design and performance evaluations of modern operating systems. Mapping and binding of addresses. Organization of multiprogramming and multiprocessing systems; interrupts, process model, and interlocks. Resource allocation models and problem of deadlocks. Scheduling, synchronization. Memory management, virtual memory. input/output (I/O) control, file systems. Letter grading.
Mr. Eggert, Mr. Kohler (W,Sp)

112. Computer System Modeling Fundamentals. (4) Lecture, four hours; outside study, eight hours. Requisite: Statistics 110A. Designed for juniors/seniors. Basic tools necessary for performance evaluation and design of distributed computer systems, including such topics as combinatorics, generating functions, probability theory, transforms, Markov chains, baby queueing theory. Presentation of this set of tools in a fashion that is rich with examples from computer systems field. Letter grading.
Mr. Muntz (F,W)

* Member of Brain Research Institute

113. Introduction to Distributed Embedded Systems. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: courses 111, 118. Introduction to basic concepts needed to understand, design, and implement wireless distributed embedded systems. Topics include design implications of energy and otherwise resource-constrained nodes, network self-configuration and adaptation, localization and time synchronization, applications, and usage issues such as human interfaces, safety, and security. Heavily project based. Letter grading.
Ms. Estrin (W)

M117. Computer Networks: Physical Layer. (6) (Formerly numbered 117.) (Same as Electrical Engineering M117.) Lecture, four hours; discussion, four hours; outside study, 10 hours. Not open to students with credit for course M171L. Introduction to fundamental data communication concepts underlying and supporting modern networks, with focus on physical and media access layers of network protocol stack. Systems include high-speed LANs (e.g., fast and giga Ethernet), optical DWDM (dense wavelength division multiplexing), time division SONET networks, wireless LANs (IEEE802.11), and ad hoc wireless and personal area networks (e.g., Bluetooth). Experimental laboratory sessions included. Letter grading.
Mr. Gerla (W)

118. Computer Network Fundamentals. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 33. Highly recommended: course 111. Designed for juniors/seniors. Introduction to design and performance evaluation of computer networks, including such topics as what protocols are, layered network architecture, Internet protocol architecture, network applications, transport protocols, routing algorithms and protocols, internetworking, congestion control, and link layer protocols including Ethernet and wireless channels. Letter grading. Mr. Gerla (F,Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: course 32. 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)

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 32, 33. Basic concepts in design and use of programming languages, including abstraction, modularity, control mechanisms, types, declarations, syntax, and semantics. Study of several different language paradigms, including functional, object-oriented, and logic programming. Letter grading. Mr. Eggert, Mr. Millstein (F,W)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 131, 181. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; theory of parsing. Letter grading. Mr. Eggert, Mr. Palsberg (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, Maisie; primitives for parallel computation: specification of parallelism, interprocess communication and synchronization; design of parallel programs for scientific computation and distributed systems. Letter grading. Mr. Bagrodia (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. Zaniolo (F,Sp)

M151B. Computer Systems Architecture. (4) (Same as Electrical Engineering M116C.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 33, and M51A 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. Reinman, Mr. Tamir (F,W,Sp)

151C. Design of Digital Systems. (4) Lecture, four hours; discussion, two hours. Requisites: courses M51A, M151B, M152A. Design of complex digital systems using hierarchal approaches and regular structures. Combinational, sequential, and algorithmic systems. Microprogramming and firmware engineering. Cost/performance measures and technology constraints. Use of design tools. Design project. Letter grading. Mr. Ercegovac (F, odd years)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical Engineering M116L.) Laboratory, four hours; outside study, two hours. Requisite: course M51A or Electrical Engineering M16. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmed array logic, design projects. Letter grading. Mr. Rennels (F,W,Sp)

M152B. Digital Design Project Laboratory. (4) (Same as Electrical Engineering M116D.) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisite: course M151B or Electrical Engineering M116C. Design and implementation of complex digital subsystems using field-programmable gate arrays (e.g., processors, special-purpose processors, device controllers, and input/output interfaces). Students work in teams to develop and implement designs and to document and give oral presentations of their work. Letter grading.
Mr. Rennels, Mr. Tamir (F,W,Sp)

161. Fundamentals of Artificial Intelligence. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: course 32. Introduction to fundamental problem solving and knowledge representation paradigms of artificial intelligence. Introduction to Lisp with regular programming assignments. State-space and problem reduction methods, brute-force and heuristic search, planning techniques, two-player games. Knowledge structures including predicate logic, production systems, semantic nets and primitives, frames, scripts. Special topics in natural language processing, expert systems, vision, and parallel architectures. Letter grading.
Mr. Darwiche, Mr. Korf (F,Sp)

163. Introduction to Natural Language Processing. (4) Lecture, four hours; laboratory, two hours. Requisite: course 130 or 131. Role of syntax, semantics, and pragmatics in human language processing by computers. Natural language generators and parsers, inference, and conceptual analysis. Modeling conceptual processes and representing semantic knowledge by means of computer problems. Letter grading. Mr. Dyer (W)

170A. Mathematical Modeling and Methods for Computer Science. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: Mathematics 33B. Introduction to methods for modeling and simulation using interactive computing environments. Extensive coverage of methods for numeric and symbolic computation, matrix algebra, statistics, floating point, optimization, and spectral analysis. Emphasis on applications in simulation of physical systems. Letter grading. Mr. Parker (Sp)

M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Electrical Engineering M171L.) Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: courses M152A, 171. Limited to seniors. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem and terminal characteristics, and interfaces. Letter grading. Mr. Gerla (F,W,Sp)

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

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

C174C. Computer Animation. (4) Lecture, four hours; discussion, two hours. Requisite: course 174A. Designed for juniors/seniors. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particles and systems, and motor control. Concurrently scheduled with course C274C. Letter grading.
Mr. Faloutsos (Sp, alternate years)

180. Introduction to Algorithms and Complexity. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32, and Mathematics 61 or 113. Designed for junior/senior Computer Science majors. Introduction to design and analysis of algorithms. Design techniques: divide-and-conquer, greedy method, dynamic programming; selection of prototypical algorithms; choice of data structures and representations; complexity measures: time, space, upper, lower bounds, asymptotic complexity; NP-completeness. Letter grading.
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: course 32, and Mathematics 61 or 113. Designed for junior/senior Computer Science majors. Grammars, automata, and languages. Finite-state languages and finite-state automata. Context-free languages and pushdown story automata. Unrestricted rewriting systems, recursively enumerable and recursive languages, and Turing machines. Closure properties, pumping lemmas, and decision algorithms. Introduction to computability. Letter grading.
Ms. Greibach, Mr. Ostrovsky (F,W,Sp)

183. Introduction to Cryptography. (4) Lecture, four hours; outside study, eight hours. Preparation: knowledge of basic probability theory. Requisite: course 180. Introduction to cryptography, computer security, and basic concepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public-key and private-key encryption, key-agreement, homomorphic encryption, private information retrieval and voting protocols, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, and two-party secure computation with static security. Letter grading.
Mr. Ostrovsky (Sp, odd years)

M186A. Introduction to Cybernetics, Biomodeling, and Biomedical Computing. (2) (Formerly numbered M196A.) (Same as Biomedical Engineering M186A and Cybernetics M186A.) Lecture, two hours. Requisites: Mathematics 31A, 31B, Program in Computing 10A. Strongly recommended for students with potential interest in biomedical engineering/biocomputing fields or in Cybernetics as a major. Introduction and survey of topics in cybernetics, biomodeling, biocomputing, and related bioengineering disciplines. Lectures presented by faculty currently performing research in one of the areas; some sessions include laboratory tours. P/NP grading.
Mr. DiStefano (F)

M186B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered M196B.) (Same as Biomedical Engineering M186B, Cybernetics M186B, and Medicine M186B.) Lecture, four hours; discussion, one hour; laboratory, two hours. Requisite: Electrical Engineering 102 or Mathematics 115A. Introduction to dynamic system modeling, compartmental modeling, and computer simulation methods for studying biomedical systems. Basics of numerical simulation algorithms, translating biomodeling goals and data into mathematic models and implementing them for simulation and analysis. Modeling software exploited for class assignments in PC laboratory. Letter grading.
Mr. DiStefano (F)

CM186L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Formerly numbered CM196L.) (Same as Biomedical Engineering CM186L and Cybernetics M186L.) Lecture, two hours; laboratory, two hours. Requisite: course M186B. Special laboratory techniques and experience in biocybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Comprehensive experiment design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM286L. Letter grading. Mr. DiStefano

188. Special Courses in Computer Science. (4) (Formerly numbered 198.) Lecture, four hours; outside study, eight hours. Special topics in computer science for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Computer Science. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field or of research of faculty members or students. Letter grading. (F,W,Sp)

199. Directed Research in Computer Science. (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. (F,W,Sp)

Graduate Courses

201. Computer Science Seminar. (2) Seminar, four hours; outside study, two hours. Designed for graduate computer science students. Seminars on current research topics in computer science. May be repeated for credit. S/U grading. (F,W,Sp)

202. Advanced Computer Science Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: completion of major field examination in computer science. Current computer science research into theory of, analysis and synthesis of, and applications of information processing systems. Each member completes one tutorial and one or more original pieces of work in the specialized area. May be repeated for credit. Letter grading. Ms. Estrin (F,W,Sp)

211. Network Protocol and Systems Software Design for Wireless and Mobile Internet. (4) Lecture, four hours; outside study, eight hours. Requisite: course 118. Designed for graduate students. In-depth study of network protocol and systems software design in area of wireless and mobile Internet. Topics include (1) networking fundamentals: design philosophy of TCP/IP, end-to-end arguments, and protocol design principles, (2) networking protocols: 802.11 MAC standard, packet scheduling, mobile IP, ad hoc routing, and wireless TCP, (3) mobile computing systems software: middleware, file system, services, and applications, and (4) topical studies: energy-efficient design, security, location management, and quality of service. Letter grading. Mr. Lu (F)

212A. Queueing Systems Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: course 112, Electrical Engineering 131A. Resource sharing issues and theory of queueing (waiting-line) systems. Review of Markov chains and baby queueing theory. Method of stages. $M/E_r/1$. $E_r/M/1$. 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; spectral solution. Inequalities, bounds, approximations. Letter grading.
Mr. Gerla (W)

212B. Queueing Applications: Scheduling Algorithms and Queueing Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 212A. Priority queueing. Applications to time-sharing scheduling algorithms: FB, Round Robin, Conservation Law, Bounds. Queueing networks: definitions; job flow balance; product form solutions — local balance, M→M; computational algorithms for performance measures; asymptotic behavior and bounds; approximation techniques — diffusion — iterative techniques; applications. Letter grading. Mr. Muntz

M213A. Embedded Systems. (4) (Formerly numbered 213.) (Same as Electrical Engineering M202A.) Lecture, four hours; outside study, eight hours. Requisite: course 111. Designed for graduate computer science and electrical engineering students. Methodologies and technologies for design of embedded systems. Topics include hardware and software platforms for embedded systems, techniques for modeling and specification of system behavior, software organization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery and energy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Theoretical foundations as well as practical design methods. Letter grading. Mr. Potkonjak, Mr. Srivistava (F)

M213B. Distributed Embedded Systems. (4) (Same as Electrical Engineering M202B.) Lecture, four hours; outside study, eight hours. Requisites: courses 111, and 118 or Electrical Engineering 132B. Designed for graduate computer science and electrical engineering students. Interdisciplinary course with focus on study of distributed embedded systems concepts needed to realize systems such as wireless sensor and actuator networks for monitoring and control of physical world. Topics include network self-configuration with localization 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 collaborative 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. S/U or letter grading.
Ms. Estrin, Mr. Srivistava (F,Sp)

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, transductions; digital data transmissions via analog signaling in computer communication; media characteristics, systems methodologies, performance analysis; modem designs; physical interfaces in computer communication links; national/international standards; tests and measurements. Letter grading. Mr. Carlyle

215. Computer Communications and Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112. Resource sharing; 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 architectures. Optional topics include extended error control techniques; modems; SDLC, HDLC, X.25, etc.; protocol verification; network simulation and measurement; integrated networks; communication processors. Letter grading. Mr. Chu (F)

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

217. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of Internet development history and fundamental principles underlying TCP/IP protocol design. Discussion of current research topics, including multicast routing protocols, multicast transport protocols (e.g., real-time, transport protocol, RTP, and SRM), support for integrated services, World Wide Web, multimedia applications on Internet. Fundamental issues in network protocol design and implementations. Letter grading. Ms. Zhang

218. Advanced Computer Networks. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 112, 118. Review of seven-layer ISO-OSI model. High-speed networks: LANs, MANs, ATM. Flow and congestion control; bandwidth allocation. Internetting. Letter grading. Mr. Gerla (W)

219. Current Topics in Computer System Modeling Analysis. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in an area of computer system modeling analysis in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading.

M222. Control and Coordination in Economics. (4) (Same as Economics M222A.) Lecture, three hours. Recommended preparation: appropriate mathematics course. Designed for graduate economics and engineering students. Stabilization policies, short- and long-run dynamics and stability analysis; decentralization, coordination in teams; certainty equivalence and separation theorems; stochastic and learning models. Bayesian approach to price and output rate adjustment. S/U or letter grading.

230A. Models of Information and Computation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131, 181. Paradigms, models, frameworks, and problem solving; UML and metamodeling; basic information and computation models; axiomatic systems; domain theory; least fixed point theory; well-founded induction. Logical models: sentences, axioms and rules, normal forms, derivation and proof, models and semantics, propositional logic, first-order logic, logic programming. Functional models: expressions, equations, evaluation; combinators; lambda calculus; functional programming. Program models: program derivation and verification using Hoare logic, object models, standard templates, design patterns, frameworks. Letter grading. Mr. Bagrodia, Mr. Parker, Mr. Zaniolo

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

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

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

234. Computer-Aided Verification. (4) Lecture, four hours. Requisite: course 181. Introduction to theory and practice of formal methods for design and analysis of concurrent and embedded systems, with focus on algorithmic techniques for checking logical properties of hardware and software systems. Topics include semantics of reactive systems, invariant verification, temporal logic model checking, theory of omega automata, state-space reduction techniques, compositional and hierarchical reasoning. Letter grading. Mr. Majumdar (F)

235. Advanced Operating Systems. (4) Lecture, four hours. Preparation: C or C++ programming experience. Requisite: course 111. In-depth investigation 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, processes, interprocess communication, preemptive multitasking, file systems. Virtualization, networking, profiling, research operating systems. Series of laboratory projects, including extra challenge work. Letter grading. Mr. Kohler (F)

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 an area of computer science programming languages and systems in which instructor has developed special proficiency as a consequence of research interests. May be repeated for credit with topic change. Letter grading.

240A. Databases and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143. Theoretical and technological foundation of Intelligent Database Systems, which merge database technology, knowledge-based systems, and advanced programming environments. Rule-based knowledge representation, spatio-temporal reasoning, and logic-based declarative querying/programming are salient features of this technology. Other topics include object-relational systems and data mining techniques. Letter grading. Mr. Zaniolo (F)

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 and object relational databases (ORDBs). Abstract data types and user-defined column functions in ORDBs. Data mining algorithms. Semistructured information. Letter grading. Mr. Muntz, Mr. Parker, Mr. Zaniolo

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

241B. Pictorial and Multimedia Database Systems. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisites: courses 143, 241A. Multimedia data: alphanumeric, long text, images/pictures, video, and voice. Multimedia information systems requirements. Data models and accessing. Querying, visual languages, and communication. Database design and organization, logical and physical. Search by content and indexing methods. Internet multimedia streaming. Data heterogeneity and distribution. Other topics at discretion of instructor. Letter grading. Mr. Cardenas

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

245A. Intelligent Information Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 241A, 255A. Knowledge discovery in database, knowledge-base maintenance, knowledge-base and database integration architectures, and scale-up issues and applications to cooperative database systems, 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 Web environment. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh techniques, Web-search ranking algorithms, and query processing techniques on independent data sources. Letter grading. Mr. Cho (F)

249. Current Topics in Data Structures. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in an area of data structures in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading.

251A. Advanced Computer Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 111. Design and implementation of high-performance systems, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW processors, branch prediction, speculative execution, software support for instruction-level parallelism, simulation-based performance analysis and evaluation, state-of-the-art design examples, introduction to parallel architectures. Letter grading. Mr. Ercegovac, 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, clusters, interconnection networks, user-level host-network interfaces, switching element design, communication primitives, cache coherency, memory consistency models, synchronization primitives, state-of-the-art design examples. Letter grading. Mr. Ercegovac, Mr. Tamir (W)

252A. Arithmetic Algorithms and Processors. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Number systems: conventional, redundant, signed-digit, and residue. Types of algorithms and implementations. Complexity measures. Fast algorithms and implementations for two-operand addition, multioperand addition, multiplication, division, and square root. On-line arithmetic. Evaluation of transcendental functions. Floating-point arithmetic and numerical error control. Arithmetic error codes. Residue arithmetic. Examples of contemporary arithmetic ICs and processors. Letter grading. Mr. Ercegovac (F)

253A. Design of Fault-Tolerant Systems. (4) Lecture, four hours; outside study, eight hours. Requisite or corequisite: course 251A. Fundamental concepts of dependable computing. Design methodology for fault-tolerant systems. Analytic models and measures, modeling tools. Design for critical applications: long-life, real-time, and high-availability systems. Tolerance of design faults: design diversity and fault-tolerant software. Letter grading. Mr. Rennels (W)

253C. Testing and Testable Design of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course M51A. Detailed study of various problems in testing and testable designs of VLSI systems, including fault modeling, fault simulation, testing for single stuck faults and multiple stuck faults, functional testing, design for testability, compression techniques, and built-in self-test. Letter grading. Mr. Cong

254A. Computer Memories and Memory Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Generic types of memory systems; control, access modes, hierarchies, and allocation algorithms. Characteristics, system organization, and device considerations of ferrite memories, thin film memories, and semiconductor memories. Letter grading. Mr. Chu, Mr. Rennels (Sp)

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

256A. Advanced Scalable Architectures: Systems, Building Blocks, and Technology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. State-of-the-art scalable multiprocessors and multicomputers. High-performance VLSI building blocks. Capabilities and limitations of VLSI technology. Interdependency among implementation technology, packaging, chip microarchitecture, and system architecture. Mechanisms for exploiting parallelism. Current research areas. Examples of chips and systems. Letter grading. Mr. Tamir (Sp)

M258A. Design of VLSI Circuits and Systems. (4) (Same as Electrical Engineering M216A.) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisites: course M51A or Electrical Engineering M16, and Electrical Engineering 115A. Recommended: Electrical Engineering 115C. LSI/VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on a chip. Letter grading. Mr. Rennels

M258B-M258C. LSI in Computer System Design. (4-4) (Same as Electrical Engineering M216B-M216C.) Lecture, four hours; laboratory, four hours. Requisite: course M258A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. In Progress (M258B) and S/U or letter (M258C) grading. Mr. Rennels

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, graph folding, floorplanning, and global routing. Letter grading. Mr. Kahng

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 a number of important optimization techniques, such as network flows, Steiner trees, simulated annealing, and generic algorithms. Letter grading. Mr. Cong (W)

258G. 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 systems, including two-level Boolean network optimization; multilevel Boolean network optimization; technology mapping for standard cell designs and field-programmable gate-array (FPGA) designs; retiming 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, 258F. 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 an area of computer science system design in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

261A. Problem Solving and Search. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. In-depth treatment of systematic 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. Korf (W)

262A. Reasoning with Partial Beliefs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112 or Electrical Engineering 131A. Review of several formalisms for representing and managing uncertainty in reasoning systems; presentation of comprehensive description of Bayesian inference using belief networks representation. Letter grading. Mr. Pearl

262B. Knowledge-Based Systems. (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

M262C. Causal Inference. (4) (Same as Statistics M241.) Lecture, four hours; outside study, eight hours. Requisite: course 112 or equivalent probability theory course. Techniques of using computers to 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

262Z. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 262A. Additional requisites for each offering announced in advance by department. Theory and implementation of systems which 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 variety of 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 161 or 163 or 263A. Examination of connectionist/ANN architectures designed for natural language processing. Issues include localist vs. distributed representations, variable binding, instantiation and inference via spreading activation, acquisition of language and world knowledge (for instance, via back propagation in PDP networks and competitive learning in self-organizing feature maps), and grounding of symbols in sensory/motor experience. Letter grading. Mr. Dyer (Sp)

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

264A. Automated Reasoning: Theory and Applications. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course 161. Introduction to theory and practice of automated reasoning using propositional and first-order logic. Topics include syntax and semantics of formal logic; algorithms for logical reasoning, including satisfiability and entailment; 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 (F)

265A. Machine Learning. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 263A, 264A. Introduction to machine learning. Learning by analogy, inductive learning, modeling creativity, learning by experience, role of episodic memory organization in learning. Examination of BACON, AM, Eurisko, HACKER, teachable production systems. Failure-driven learning. Letter grading. Mr. Dyer

267A. Neural Models. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Review of major neurophysiological milestones in understanding brain architecture and processes. Focus on brain theories that are important for modern computer science and, in particular, on models of sensory perception, sensory-motor coordination, and cerebellar and cerebral structure and function. Students required to prepare a paper analyzing research in one area of interest. Letter grading. Mr. Vidal

267B. Artificial Neural Systems and Connectionist Computing. (4) Lecture, four hours; outside study, eight hours. 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 to associative knowledge processing, general multisensor pattern recognition including speed and vision, and adaptive robot control. Students required to prepare a paper analyzing research in one area of interest. Letter grading. Mr. Vidal

268. Machine Perception. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Computational aspects of processing visual and other sensory information. Unified treatment of early vision in man and machine. Integration of symbolic and iconic representations in process of image segmentation. Computing multimodal sensory information by "neural-net" architectures. Letter grading. Mr. Dyer

268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, six hours. Designed for students undertaking thesis research. Discussion of advanced topics and current research in computational neuroscience. Neural networks and connectionism as a paradigm for parallel and concurrent computation in application to problems of perception, vision, multimodal sensory integration, and robotics. May be repeated for credit. S/U grading.

269. Seminar: Current Topics in Artificial Intelligence. (2 to 4) Seminar, to be arranged. Review of current literature and research practicum in an area of artificial intelligence in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

270A. Computer Methodology: Advanced Numerical Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 103 or Mathematics 151B or comparable experience with numerical computing. Designed for graduate computer science and engineering students. Principles of computer treatment of selected numerical problems in algebraic and differential systems, transforms and spectra, data acquisition and reduction; emphasis on concepts pertinent to modeling and simulation and the applicability of contemporary developments in numerical software. Computer exercises. Letter grading. Mr. Carlyle (F)

271A. Modeling and Simulation of Lumped Parameter Systems. (4) Lecture, eight hours. Recommended preparation: course 270A. Characterization of electrical, electromechanical, and other engineering problems by systems of nonlinear ordinary differential equations. Survey of integration algorithms. Digital simulation languages for continuous systems. Real-time simulation using array processor and multiprocessor computer systems. Letter grading. (W)

271B. Modeling and Simulation of Distributed Parameter Systems. (4) Lecture, eight hours. Recommended preparation: course 270A. Mathematical formulation of engineering field problems governed by partial differential equations. Finite difference and finite element approximations. Principal algorithms for solving elliptic, parabolic, and hyperbolic partial differential equations. Supercomputers, vector processors, multiprocessors, and array processors. Letter grading. (Sp)

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

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

273A. Digital Processing of Engineering and Statistical Data. (4) Lecture, four hours; outside study, eight hours. Computer methods for processing engineering and statistical data. Algorithms to evaluate recursive filter functions, Fourier series, power spectral, analysis correlation computations, and statistical testing. Letter grading.

C274C. Computer Animation. (4) Lecture, four hours; recitation, two hours. Requisite: course 174A. Introduction to computer animation, including basic principles of character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particles and systems, and motor control. Concurrently scheduled with course C174C. Letter grading. Mr. Faloutsos (Sp, alternate years)

M276A. Pattern Recognition and Machine Learning. (4) (Formerly numbered 276A.) (Same as Statistics M231.) Lecture, three hours. Designed for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are used in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering, complexity (VC-dimension, MDL, AIC), PCA/ICA/TCA, MDS, SVM, boosting. S/U or letter grading. Mr. Zhu

276B. Structured Computer Vision. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Methods for computer processing of image data. Systems, concepts, and algorithms for image analysis, radiologic and robotic applications. Letter grading. Mr. Klinger

276C. Speech and Language Communication in Artificial Intelligence. (4) Lecture, four hours; outside study, eight hours. Requisite: course M276A or 276B. Topics in human-computer communication: interaction with pictorial information systems, sound and symbol generation by humans and machines, semantics of data, systems for speech recognition and understanding. Use of speech and text for computer input and output in applications. Letter grading. Mr. Klinger

279. Current Topics in Computer Science: Methodology. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in an area of computer science methodology in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. (F,W,Sp)

280A-280ZZ. Algorithms. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections from design, analysis, optimization, and implementation of algorithms; computational complexity and general theory of algorithms; algorithms for particular application areas. Subtitles of some current sections: Principles of Design and Analysis (280A); Distributed Algorithms (280D); Graphs and Networks (280G). May be repeated for credit with consent of instructor and with topic change. Letter grading. Ms. Greibach (F,W,Sp)

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or compatible background. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets, closure properties, machine characterizations, nondeterminisms, decidability, unsolvable problems, "easy" and "hard" problems, PTIME/NPTIME. Letter grading. Ms. Greibach, Mr. Parker

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 181. Finite-state machines, transducers, and their generalizations; regular expressions, transduction expressions, realizability; decomposition, synthesis, and design considerations; topics in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system modeling, and simulation. Letter grading. Mr. Carlyle

M282A. Cryptography. (4) (Formerly numbered 282A.) (Same as Mathematics M209A.) Lecture, four hours; outside study, eight hours. Introduction to theory of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public-key and private-key encryption, secret-sharing, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, key-agreement, contract signing, and two-party secure computation with static security. Letter grading. Mr. Ostrovsky (W)

M282B. Cryptographic Protocols. (4) (Formerly numbered 282B.) (Same as Mathematics M209B.) Lecture, four hours; outside study, eight hours. Requisite: course M282A. Consideration of advanced cryptographic protocol design and analysis. Topics include noninteractive zero-knowledge proofs; zero-knowledge arguments; concurrent and non-black-box zero-knowledge; IP=PSPACE proof, stronger notions of security for public-key encryption, including chosen-ciphertext security; secure multiparty computation; dealing with dynamic adversary; nonmalleability and composability of secure protocols; software protection; threshold cryptography; identity-based cryptography; private information retrieval; protection against man-in-middle attacks; voting protocols; identification protocols; digital cash schemes; lower bounds on use of cryptographic primitives, software obfuscation. May be repeated for credit with topic change. Letter grading. Mr. Ostrovsky (W)

M283A-M283B. Topics in Applied Number Theory. (4-4) (Same as Mathematics M208A-M208B.) Lecture, three hours. Basic number theory, including congruences and prime numbers. Cryptography: public-key and discrete log cryptosystems. Attacks on cryptosystems. Primality testing and factorization methods. Elliptic curve methods. Topics from coding theory: Hamming codes, cyclic codes, Gilbert/Varshamov bounds, Shannon theorem. S/U or letter grading.

284A-284ZZ. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 181. Additional requisites for each offering announced in advance by department. Selections from families of formal languages, grammars, machines, operators; pushdown automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Subtitles of some current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284P). May be repeated for credit with consent of instructor and with topic change. Letter grading. Ms. Greibach

CM286L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Formerly numbered CM296L.) (Same as Biomedical Engineering CM286L.) Lecture, two hours; laboratory, two hours. Requisite: course M186B. Special laboratory techniques and experience in biocybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Comprehensive experiment design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM186L. Letter grading. Mr. DiStefano

287A. Theory of Program Structure. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Models of computer programs and their syntax and semantics; emphasis on programs and recursion schemes; equivalence, optimization, correctness, and translatability of programs; expressive power of program constructs and data structures; selected current topics. Letter grading. Ms. Greibach

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisites: courses 280A, 281A. Intended for students undertaking thesis research. Discussion of advanced topics and current research in such areas as algorithms and complexity models for parallel and concurrent computation, and formal language and automata theory. May be repeated for credit. S/U grading. Ms. Greibach (F,W,Sp)

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

289OA. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Introduction to decision making under uncertainty and competitive analysis. Review of current research in online algorithms for problems arising in many areas, such as data and memory management, searching and navigating in unknown terrains, and server systems. Letter grading.
Mr. Meyerson (Sp, alternate years)

289RA. Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomized algorithms, such as probability theory, Markov chains, random walks, and probabilistic method. Applications to randomized algorithms in data structures, graph theory, computational geometry, number theory, and parallel and distributed systems. Letter grading. Mr. Meyerson

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

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

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Same as Biomedical Engineering M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296A. Recommended: course M296B. Research techniques and experience on special topics involving models, modeling methods, and model/computing in biological and medical sciences. Review and critique of literature. Research problem searching and formulation. Approaches to solutions. Individual M.S.- and Ph.D.-level project training. Letter grading. Mr. DiStefano

M296D. Introduction to Computational Cardiology. (4) (Same as Biomedical Engineering M296D.) Lecture, four hours; outside study, eight hours. Requisite: course M186B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.
Mr. DiStefano, Mr. Kogan (Sp)

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

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

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

596. Directed Individual or Tutorial Studies. (2 to 8) Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. 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 computer science students. Reading and preparation for M.S. comprehensive examination. S/U grading.

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

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

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

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. S/U grading.

Electrical Engineering

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Giorgio Franceschetti, Ph.D.
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Joel Schulman, Ph.D.
Ming C. Wu, Ph.D.

Adjunct Associate Professors
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William H. Mangione-Smith, Ph.D.

Adjunct Assistant Professor
Charles Chien, Ph.D.

Scope

The Electrical Engineering Department emphasizes teaching and research in the fields of communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization/operations research, integrated circuits and systems, microelectromechanical systems/nanotechnology (MEMS/nano), photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. In each of these fields, the department has state-of-the-art research programs and facilities exploring exciting new concepts and developments. Undergraduate students receive a B.S. degree in Electrical Engineering. Graduate research and training programs leading to the M.S. and Ph.D. degrees are also offered.

The department is associated with several research centers, including the Center for High-Frequency Electronics (CHFE), Plasma Science and Technology Institute, Flight Systems Research Center (FSRC), Center for Embedded Networked Sensing (CENS), Functional Engineered Nano Architectonics Focus Center (FENA), and Center for Nanoscience Innovation for Defense (CNID).

Department Mission

In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the Electrical Engineering Department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental and cutting-edge technical knowledge in electrical engineering to serve 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 by expanding the body of knowledge in the field, (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 gives an excellent background for either graduate study or employment. In consultation with its constituents, the Electrical Engineering Department has set its educational objectives as follows: (1) fundamental knowledge, whereby program graduates are skilled in the fundamental concepts of electrical engineering necessary for success in industry or graduate school, (2) specialization, whereby program graduates are prepared to pursue career choices in electrical engineering, computer engineering, biomedical engineering, or related interdisciplinary fields that benefit from a strong background in applied sciences or engineering, (3) design skills, whereby program graduates are prepared with problem-solving, laboratory, and design skills for technical careers, (4) professional skills, whereby program graduates are prepared with communication and teamwork skills as well as an appreciation for ethical behavior necessary to thrive in their careers, and (5) self-learning, whereby program graduates are prepared to continue their professional development through continuing education and personal development experiences based on their awareness of library resources and professional societies, journals, and meetings.

Electrical Engineering B.S.

The Major

Course requirements are as follows (190 minimum units required):

1. One engineering breadth course from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A)

2. Electrical Engineering 10, M16 (or Computer Science M51A), 101, 102, 103, 110, 110L, 113, 115A, 115AL, 121B, 131A, 132A, 141, 161, 172, Mathematics 113 or 132, Mechanical and Aerospace Engineering 182A
3. Five major field elective courses (18 units minimum) selected from those offered by the Electrical Engineering Department. Of the five courses, one laboratory course (4 units) and one design course (4 units) are required. With approval of the adviser, two may be selected from courses related to electrical engineering in other departments
4. Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31, 32; Electrical Engineering 1, 2; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Biomedical Engineering Option

Course requirements are as follows (201 minimum units required):

1. Electrical Engineering 10, M16 (or Computer Science M51A), 101, 102, 103, 110, 110L, 113, 114D, 115A, 115AL, 121B, 131A, 132A, 141, 161, Mathematics 113 or 132, Mechanical and Aerospace Engineering 103, M105A, 182A
2. Life Sciences 1 (satisfies HSSEAS GE life sciences requirement), 2, 3
3. Three technical electives, including one course selected from Electrical Engineering 115B, 115C, 142, 172; the remaining two courses may be selected from the above list and/or from Biomedical Engineering C101, CM102, CM103, Computer Science M186B, CM186L, Electrical Engineering 176
4. Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL; Computer Science 31; Electrical Engineering 1, 2; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Computer Engineering Option

Course requirements are as follows (190 minimum units required):

1. One engineering breadth course from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A)
2. Computer Science 111, 180, Electrical Engineering 10, M16 (or Computer Science M51A), 101, 102, 103, 110, 110L, 113, 115A, 115AL,115C, M116C (or Computer Science M151B), M116D (or Computer Science M152B), M116L (or Computer Science M152A), 121B, 131A, Mathematics 113 or 132, Mechanical and Aerospace Engineering 182A
3. Four technical elective courses, one of which must be Electrical Engineering 132A or either Computer Science 118 or Electrical Engineering 132B. The remaining three courses must be upper division electrical engineering or computer science courses, and at least three of the four must be from the Electrical Engineering Department
4. Chemistry and Biochemistry 20A; Computer Science 31, 32, 33; Electrical Engineering 1, 2; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Departures from the stated requirements are possible, and students who wish to follow programs that cannot be accommodated within these requirements may prepare, in consultation with their advisers, proposals for consideration by the department. Variations are approved if the overall program has a well-defined educational objective and is substantially equivalent to the existing curriculum in breadth and depth.

Graduate Study

For information on graduate admission see Graduate Programs, page 24.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the "Publications" link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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.

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. A majority of the courses must be in or related to electrical engineering and belong to one of the specialized major fields described below.

Undergraduate Courses. Lower and upper division undergraduate courses required for any of the B.S. options in Electrical Engineering cannot be applied toward graduate degrees.

In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 105D, 199.

Communications and Telecommunications

Requisite. B.S. degree in Engineering or equivalent.

Minimum Course Requirements. Nine 4-unit courses, of which at least six must be graduate courses.

Thesis Plan. Electrical Engineering 230A, 232A; two additional 200-level electrical engineering courses in the communications and telecommunications engineering area; three or more courses, of which at least two must be 200-level electrical engineering courses, subject to the approval of the student's adviser. Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses.

Comprehensive Examination Plan. Electrical Engineering 230A, 232A; two additional 200-level electrical engineering courses in the communications and telecommunications engineering area; five or more courses, of which at least two must be 200-level electrical engineering courses, subject to the approval of the student's adviser.

Control Systems

Requisite. B.S. degree in Electrical Engineering or equivalent.

Thesis Plan. Seven graduate-level courses, of which at least five must be selected from the list of courses covering the control systems fundamentals, and a thesis. The remaining courses are subject to the approval of the student's adviser. In addition, 8 units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis.

Comprehensive Examination Plan. Nine courses, of which seven must be graduate courses and at least five must be selected from the list of courses covering the control systems fundamentals. The remaining courses are subject to the approval of the student's adviser.

Basic graduate courses in control systems fundamentals: Electrical Engineering M240A, 240B, M240C, 241A, 241B, 241C, M242A.

Electromagnetics

Requisite. B.S. degree in Electrical Engineering or equivalent.

Thesis Plan. Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses, but only one can count toward the requirement of five graduate-level courses. A minimum of four graduate courses is to be selected from the Group II list.

The remaining courses may, subject to the approval of the student's adviser, be selected as free electives from the 100 or 200 series in order to meet the overall requirements given above.

Comprehensive Examination Plan. At least seven courses must be selected from those listed below in Groups I and II, and at least four of the seven courses must be selected from Group II.

The remaining two courses may, subject to the approval of the student's adviser, be selected as free electives from the 100 or 200 series in order to meet the overall requirements given above.

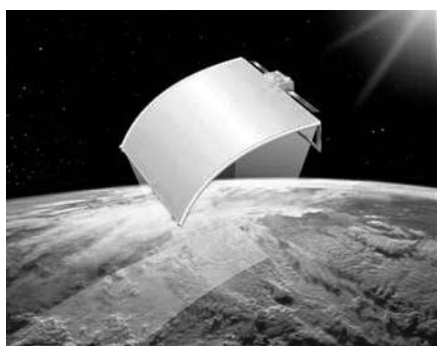
Group I: Electrical Engineering 162A, 163A, 163B, 163C, M185.

Group II: Electrical Engineering 221C, 260A, 260B, 261, 262, 263, 266, 270.

Embedded Computing Systems

Requisite: B.S. degree in Electrical Engineering or Computer Engineering.

Thesis Plan. Nine courses, of which at least six must be graduate courses, and a thesis. The three courses in Group I must be completed, and at least three courses must be selected from Group II. The remaining three courses may be selected as free electives. Eight units (two courses) of Electrical Engineering 598 may be applied as free electives.



Membrane spaceborne antenna for remote sensing applications

Comprehensive Examination Plan. Nine courses, of which at least six must be graduate courses. The three courses in Group I must be completed, and at least three courses must be selected from Group II. The remaining three courses may be selected as free electives.

Group I: Electrical Engineering 201A, M202A, 204A.

Group II: Electrical Engineering M202B, 213A, M216A, Computer Science 251A, 252A.

Free Electives. All 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser and major field chair. However, students are strongly encouraged to take these courses from allied major fields, such as communications and telecommunications, integrated circuits and systems, and signal processing. Undergraduate core courses may not be applied as free electives.

Engineering Optimization/ Operations Research

Requisite. B.S. degree in Engineering or Mathematical Sciences or equivalent.

Minimum Course Requirements. At least nine courses, of which at least five must be graduate courses. For the requisite structure, consult the department.

In consultation with an adviser, students may elect the thesis plan or the comprehensive examination plan. M.S. students in either plan must take at least three courses from Group I and at least two courses from Group II.

Group I: Optimization (Mathematical Programming): Electrical Engineering 232E, 236A, 236B, 236C.

Group II: Applied Stochastic Processes and Dynamic Programming: Electrical Engineering 232A, 232B, 232C, M237.

Thesis Plan. Under the thesis plan, students must take 8 units (two courses) of Electrical Engineering 598 to cover the research work and preparation of the thesis. Only 4 of these units may be used to satisfy the graduate course requirement; however, the 8 units can be used to satisfy the total course requirement.

Comprehensive Examination Plan. Under the comprehensive examination plan, students may not apply any 500-level courses toward the course requirements.

Integrated Circuits and Systems

Requisite. B.S. degree in Electrical Engineering or equivalent, with strong emphasis on circuit design. Coursework must have covered the material contained in Electrical Engineering 113, 115B, and 115C.

Minimum Course Requirements. Nine courses, of which at least six must be graduate courses. A thesis must be completed under the direction of a faculty adviser.

Thesis Plan. The three courses in Group I must be completed. In addition, three courses must be selected from Groups II and III with, at most, one from Group III. The remaining three courses may be selected as free electives.

Comprehensive Examination Plan. Eleven graduate courses, including the three courses in Group I and at least six courses from Groups II and III, with no more than two courses from Group III. Two elective courses may be taken from any 200-level courses in the department. The courses must be taken for letter grades and are subject to the approval of the faculty adviser. Undergraduate courses may not be applied.

Group I: Electrical Engineering 215A, 215B, M216A.

Group II: Electrical Engineering 201A, M202A, 212A, 212B, 213A, 215C, 215D, 215E.

Group III: Computer Science 251A, 252A 253C.

Free Electives. With some exceptions, all 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser. However, it is strongly recommended that courses from the fields of communications and telecommunications, signal processing, and solid-state electronics be used as the free electives. Undergraduate core courses in the Electrical Engineering Department and HSSEAS may not be applied as free electives. Electrical Engineering 598 may be applied as one of the three electives.

The normal courseload approved by a faculty adviser is such that it requires a full-time presence on campus and, as a rule, precludes part-time off-campus employment. The M.S. program should normally take four quarters and a summer for completion.

Microelectromechanical Systems/ Nanotechnology (MEMS/Nano)

Requisite. B.S. degree in Electrical Engineering, Mechanical Engineering, Physics, or equivalent.

Minimum Course Requirements. At least nine graduate and upper division courses (36 units) must be completed in graduate standing. At least six courses (24 units) must be graduate 200-level courses. All courses in Group I (14 units) must be completed, and at least one course (4 units) must be selected from Group II. The remaining 18 units may be free electives, but 12 units must be at the graduate level.

Comprehensive Examination Plan. Course requirements listed above and the comprehensive examination must be completed.

Thesis Plan. Course requirements listed above and a thesis, which must be reviewed by a committee of at least three faculty members who hold regular professorial appointments at the University (no adjunct or visiting professors), must be completed. A maximum of 8 units (two courses) of Electrical Engineering 598 may be applied as free electives, but only 4 units (one course) may be applied as one of the six required graduate-level courses. Thesis-plan students who complete only 4 units of course 598 are required to complete four elective courses (16 units), at least three of which must be graduate-level courses. Thesis-plan students who complete 8 units of course 598 are required to complete three elective courses (12 units), at least two of which must be graduate-level courses.

Group I: Electrical Engineering M150, M150L, M250A, M250B.

Group II: Mechanical and Aerospace Engineering 281, 284.

Free Electives. All 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser and the chair of the MEMS/nanotechnology major field. Since the field of MEMS/nanotechnology is broadly applicable, students may take these courses from any of the other major fields in electrical engineering, as well as those fields of particular relevance to MEMS/nanotechnology that are outside the Electrical Engineering Department (e.g., mechanical engineering, materials science, bioengineering, chemical engineering, chemistry, physics). Undergraduate core courses may not be applied as free electives. An undergraduate course that is a requisite for a graduate course may not be taken after the graduate course.

Photonics and Optoelectronics

Requisite. B.S. degree in Engineering or Physics or equivalent.

Thesis Plan. Electrical Engineering 270, 271, either 272 or 273 or 274, 598 (twice), and four additional courses, of which at least one must be a 200-level course.

Comprehensive Examination Plan. Electrical Engineering 270, 271, either 272 or 273 or 274, and six additional courses, of which at least two must be 200-level courses.

Additional Courses. With a few exceptions, all 100- and 200-level courses in the *UCLA General Catalog* are acceptable subject to the approval of the adviser. The exceptions are the following courses (which are not acceptable for any M.S. program in Electrical Engineering): (1) all school undergraduate core courses and (2) all department undergraduate core courses. Consult the departmental adviser for lists of the courses.

Plasma Electronics

Requisite. B.S. degree in Engineering or Physics or equivalent.

Thesis Plan. Electrical Engineering M185, 285A, 285B, 598 (twice), and four additional courses from the list below. Of these, at least two must be in the 200 series and at least one must be in electrical engineering. If Electrical Engineering M185 was taken as an undergraduate, it may be replaced by any engineering course on the list below.

Comprehensive Examination Plan. Electrical Engineering M185, 285A, 285B, and six additional courses from the list below. Of these, at least three must be in the 200 series and at least one must be in electrical engineering. Of the remainder, at least one other course must be in engineering. If Electrical Engineering M185 was taken as an undergraduate, it may be replaced by any course on the list below. Other courses may be substituted with the consent of the department adviser.

Additional Courses. Electrical Engineering 115A, 115AL, 115B, 115BL, 115C, 122L, 123A, 123B, 124, 162A, 163A, 163B, 164L, 172, 208A, 208B, 270, 271, 272, M287, Mechanical and Aerospace Engineering 150A, 150B, 250A, 252A, 252B, Physics 160, 180E, 222A, 222B, 222C, 231A, 231B.

Signal Processing

Requisite. B.S. degree in Electrical Engineering.

Minimum Course Requirements. Nine 4-unit courses, of which at least seven must be graduate courses.

Thesis Plan. A thesis must also be completed under the direction of a faculty adviser. Eight units (two courses) of Electrical Engineering 598 can be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses, but only one counts toward the seven graduate-level courses. The four courses in Group I must be completed, and at least two courses must be selected from Group II. The two courses from Group II may be substituted by other 200-level electrical engineering courses with the approval of the student’s faculty adviser. The remaining courses may be selected as free electives and/or Electrical Engineering 598.

Comprehensive Examination Plan. The four courses in Group I must be completed, and at least two courses must be selected from Group II. The two courses from Group II may be substituted by other 200-level electrical engineering courses with the approval of the student's faculty adviser. The remaining courses may be selected as free electives.

Group I: Electrical Engineering 210A, 211A, 212A, M214A.

Group II: Electrical Engineering 210B, 211B, 212B, 213A, 214B, M216A.

Free Electives. All 100- and 200-level courses in the *UCLA General Catalog* are acceptable as free electives with the exception of undergraduate core courses in HSSEAS and undergraduate Electrical Engineering Department core courses. The choice of free electives must be approved by the faculty adviser.

Solid-State Electronics

Requisite. B.S. degree in Engineering or equivalent.

Minimum Course Requirements. Nine courses, of which at least five must be graduate courses. The program must include all core courses listed below with the remaining courses selected from the options list. Additional options may be applied with the consent of the adviser.

Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses, but only one counts toward the five required graduate-level courses.

Solid-State Physical Electronics Requirements. Core: Electrical Engineering 123B, 124, 223. Options: At least two courses from Electrical Engineering 221A, 221B, 221C, 224, and 225, with the remaining courses from graduate courses and those upper division courses that are not required for the B.S. degree in Electrical Engineering, with approval of the graduate adviser.

Semiconductor Device Physics and Design Requirements. Core: Electrical Engineering 123B, 124, 221A, 221B. Options: At least two courses from Electrical Engineering 221C, 222, 223, 224, 225, and 298 (in solid-state electronics), with the remaining courses from graduate courses and those upper division courses that are not required for the B.S. degree in Electrical Engineering, with approval of the graduate adviser.

Comprehensive Examination Plan

Communications and Telecommunications

A written comprehensive examination is administered by the communications and telecommunications field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the communications and telecommunications field.

Control Systems

A written comprehensive examination, administered by a three-person committee chaired by a member of the controls field committee, must be taken during the last quarter of study toward the M.S. degree. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Electromagnetics

A common six- to eight-hour comprehensive examination is offered once a year to students in this M.S. program. The examination must be taken during the academic year at the end of which students are expected to graduate. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Embedded Computing Systems

Students are required to pass a written examination scheduled by the embedded computing systems field chair to be concurrent with the Ph.D. preliminary examination.

Engineering Optimization/Operations Research

Students take a common written examination during their last quarter of coursework. The examination is normally offered at the end of Fall and Spring Quarters. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Integrated Circuits and Systems

A written comprehensive examination is administered by the integrated circuits and systems field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the integrated circuits and systems field.

Microelectromechanical Systems/Nanotechnology

Students are required to pass a written examination scheduled by the microelectromechanical systems/nanotechnology (MEMS/nano) field chair to be concurrent with the Ph.D. preliminary examination.

Photonics and Optoelectronics

Consult the department. In case of failure of the comprehensive examination, students may be reexamined once with the consent of the graduate adviser.

Plasma Electronics

Consult the department. The majority of M.S. candidates proceed to the Ph.D. The Ph.D. qualifying examination may be taken to satisfy the M.S. comprehensive examination requirement.

Signal Processing

A written comprehensive examination is administered by the signal processing field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the signal processing field.

Solid-State Electronics

The comprehensive examination plan is not offered.

Thesis Plan

Consult the department for information on the thesis plan for the areas of communications and telecommunications, control systems, electromagnetics, engineering optimization/operations research, photonics and optoelectronics, and plasma electronics.

Embedded Computing Systems

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted concurrently with the coursework.

Integrated Circuits and Systems

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted in the Integrated Circuits and Systems Laboratory concurrently with the coursework.

Microelectromechanical Systems/Nanotechnology

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted concurrently with the coursework.

Signal Processing
A thesis must be completed under the direction of a faculty adviser.

Solid-State Electronics
A thesis is required. Consult the department for details.

Electrical Engineering Ph.D.

Major Fields or Subdisciplines

Communications and telecommunications; control systems; electromagnetics; embedded computing systems; engineering optimization/operations research; integrated circuits and systems; microelectromechanical systems/nanotechnology (MEMS/nano); photonics and optoelectronics; plasma electronics; signal processing; solid-state electronics.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may theoretically substitute coursework by examinations. Normally, however, students 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. A detailed syllabus describing each major field can be obtained in the department office. The major field has a scope corresponding to a body of knowledge contained in six courses, at least four of which are graduate courses, plus the current literature in the area of specialization. Each major field named above is described in a Ph.D. major field syllabus. 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. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor fields are usually selected to support the major field and are usually subsets of other major fields.

Written and Oral Qualifying Examinations

The written qualifying examination is known as the Ph.D. preliminary examination in HSSEAS. After mastering the body of knowledge defined in the major field, students take a preliminary examination in the major field. The examination typically consists of both a written part and an oral part, and students pass the entire examination and not in parts. The oral part does not exceed two hours and in some major fields is not required at all. Students who fail the examination may repeat it once only, subject to the approval of the major field committee. The major field examination, together with the three courses in a minor field, should be completed within six quarters after admission to the Ph.D. program.

After passing the written qualifying examination described above, students take the University Oral Qualifying Examination, which should occur within three quarters after completing the written examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student's preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are “inside” members and must hold appointments at UCLA in the student’s major department in HSSEAS. The “outside” member must be a UCLA faculty member outside the student’s major department.

Fields of Study

Communications and Telecommunications

Communications and telecommunications research is concerned with communications, telecommunications, networking, and information processing principles and their engineering applications. Communications research includes satellite, spread spectrum, and digital communications systems. Fast estimation, detection, and optimization algorithms and processing techniques for communications, radar, and VLSI design are studied. Research is conducted in stochastic modeling of telecommunications engineering systems, switching, architectures, queueing systems, computer communications networks, local-area/metropolitan-area/long-haul communications networks, optical communications networks, packet-radio and cellular radio networks, and personal communications systems. Research in networking also includes studies of processor communications and synchronization for parallel and distributed processing in computer and sensor network systems. Several aspects of communications networks and processing systems are thoroughly investigated, including system architectures, protocols, performance modeling and analysis, simulation studies, and analytical optimization. Investigations in information theory involve basic concepts and practices of channel and source coding. Significant multidisciplinary programs including sensing and radio communication networks exist.

Control Systems

Faculty and students in the control systems field conduct research in control, estimation, filtering, and identification of dynamic systems, including deterministic and stochastic, linear- and nonlinear-, and finite- and infinite-dimensional systems. Topics of particular interest include adaptive, distributed, nonlinear, optimal, and robust control, with applications to autonomous systems, smart structures, flight systems, microbiotics, microelectromechanical systems, and distributed networks.

Electromagnetics

Research in electromagnetics is conducted on novel integrated three-dimensional microwave and millimeter wave circuits, components, and systems, printed antennas, wireless and personal communications, fiber optics, integrated optics and photonic bandgap wave-guiding structures, left-handed transmission structures, antenna theory and design, satellite antennas, smart antennas and materials, antennas and biological tissue interactions, modern antenna near field measurement techniques, microwave holography and antenna diagnostics, radar cross section, multiple scattering, genetic algorithms, ultra wideband radar, radar signal processing, time domain electromagnetics, novel time domain, advanced EM numerical techniques, and parallel computational techniques.

Embedded Computing Systems

Faculty in the embedded computing systems field conduct research in areas including processor architectures and VLSI design methodologies for real-time embedded systems in application domains such as cryptography, digital signal processing, algebra, wireless and high-speed communications, mobile and wireless multimedia systems, distributed wireless sensor networks, power-aware computing and communications, quality of service, quantum and nanoelectronic computation, quantum information processing, fault-tolerant computation, combinatorics and information theory, advanced statistical processing, adaptive algorithms, dynamic circuits to implement configurable computing systems, low-power processor and system design, multimedia and communications processing, and all techniques for leveraging instruction-level parallelism.

Engineering Optimization/ Operations Research

Engineering optimization/operations research is conducted in optimization theory, including linear and nonlinear programming, convex optimization and engineering applications, numerical methods, nonconvex programming, and associated network flow and graph problems. Another area of study is that of stochastic processes, including renewal theory, Markov chains, stochastic dynamic programming, and queueing theory. Applications are made to a variety of engineering design problems, including communications and telecommunications.

Integrated Circuits and Systems

Students and faculty in integrated circuits and systems (IC&S) are engaged in research on communications and RF integrated circuit design; analog and digital signal processing microsystems; integrated microsensors and associated low-power microelectronics; reconfigurable computing systems; and multimedia and communications processors. Current projects include wireless transceiver integrated circuits, including RF and baseband circuits; high-speed data communications integrated circuits; A/D and D/A converters; and digital processor design. M.S. and Ph.D. degrees require a thesis based on an ongoing IC&S project and full-time presence on campus. More information is at http://www.icsl.ucla.edu.

Microelectromechanical Systems/ Nanotechnology

The microelectromechanical systems/nanotechnology (MEMS/nano) program is one of the fastest growing research programs in the school, with faculty and student participation from the Departments of Electrical Engineering, Mechanical and Aerospace Engineering, Materials Science and Engineering, Chemical and Biomolecular Engineering, and Biomedical Engineering. Inside the Electrical Engineering Department, the program has attracted students from solid-state electronics, integrated circuits and systems, photonics and optoelectronics, electromagnetics, computer engineering, and control systems. MEMS/nano research at UCLA emphasizes the design, fabrication, and physics of sensors, actuators, and systems on a nanometer to millimeter scale. Research project areas include free-space micro optics (MOEMS), biology and medicine (BioMEMS), neuroengineering, advanced circuit integration with MEMS, reconfigurable electromagnetic systems (RF MEMS, millimeter wave devices, antennas), fluid dynamics, and distributed sensor and actuator networks.

Photonics and Optoelectronics

The photonics and optoelectronics group conducts research on photonic and optoelectronic devices, circuits, and systems. Target applications include but are not limited to telecommunication, data communication, phased array antenna systems, radar, CATV and HFC networks, and biomedicine. Among technologies being developed are nonlinear optical devices, ultrafast photodetectors and modulators, infrared detectors, mode-locked lasers, photonic bandgap devices, DWDM, CDMA, true time delay beam steering, temporal manipulation techniques and data conversion, digital and analog transceivers, optical MEMS, and biomedical sensors. Laboratory facilities host the latest technology in lasers, optical measurements, Gbit/s bit error rate testing, and millimeter wave optoelectronic characterization. UCLA photonics hosts several national research centers including the DARPA Consortium for Optical A/D System Technology (COAST), the Navy MURI Center on RF Photonics, and the Army MURI Center on Photonic Bandgap Research. The group is a member of the Optoelectronic Industry Development Association (OIDA).

Plasma Electronics

Plasma electronics research is concerned with a basic understanding of both inertially confined and magnetically confined fusion plasmas, as well as with the applications of plasma physics in areas such as laser plasma accelerators, ion beam sources, plasma-materials processing, and free-electron lasers. Extensive laboratory facilities are available, including high-power lasers and microwave and millimeter wave sources and detectors, a state-of-the-art laser and beam physics laboratory for advanced accelerator studies, and large quiescent low-density plasmas for nonlinear wave studies. In addition, experiments are conducted at a variety of national laboratories.

Signal Processing

Signal processing encompasses the techniques, hardware, algorithms, and systems used to process one-dimensional and multidimensional sequences of data. Research being conducted in the signal processing group reflects the broad interdisciplinary nature of the field today. Areas of current interest include analysis, synthesis, and coding of speech signals, video signal processing, digital filter analysis and design, multirate signal processing, image compression, adaptive filtering, communications signal processing, equalization techniques, synthetic aperture radar remote sensing, signal processing for hearing aids, auditory system modeling, automatic speech recognition, wireless communication, digital signal processor architectures, and the characterization and analysis of three-dimensional time-varying medical image data. The M.S. program includes a thesis project or a comprehensive examination.

Solid-State Electronics

Solid-state electronics research involves studies of new and advanced devices with picosecond switching times and high-frequency capabilities up to submillimeter wave ranges. Topics being investigated are hot electron transistors, quantum devices, heterojunction bipolar transistors, HEMTs, MESFETs, ultra-scaled MOSFETs, SOI devices, bipolar devices, and photovoltaic devices. The studies of basic materials, submicron structures, and device principles range from Si, Si-Ge, Si-Silicides, and III-V molecular beam epitaxy to the modeling of electron transport in high fields and short temporal and spatial scales. Research in progress also includes fabrication, testing, and reliability of new types of VLSI devices and circuits.

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.

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. A goal of the center is to combine, in a synergistic manner, five new 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, etc.), (4) GaAs gigabit logic systems, and (5) VLSI and LSI based on new materials and structures. The center supports work in these areas by providing the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations into new electronic devices. Students, both graduate and undergraduate, receive training and instruction in a unique facility.

The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different interdependent fields. The Electrical Engineering Department, other departments within UCLA, and local universities (such as Cal Tech and USC) have begun to combine and correlate certain research programs as a result of the formation of the center. Students and faculty are encouraged to become active in using the center's facilities, attending its seminars, and participating in innovative new research programs. For more information, see http://chfe.ee.ucla.edu.

Circuits Laboratories

The Circuits Laboratories are equipped for measurements on high-speed analog and digital circuits and are used for the experimental study of communication, signal processing, and instrumentation systems.

A hybrid integrated circuit facility is available for rapid mounting, testing, and revision of miniature circuits. These include both discrete components and integrated circuit chips. The laboratory is available to advanced undergraduate and graduate students through faculty sponsorship on thesis topics, research grants, or special studies.

Electromagnetics Laboratories

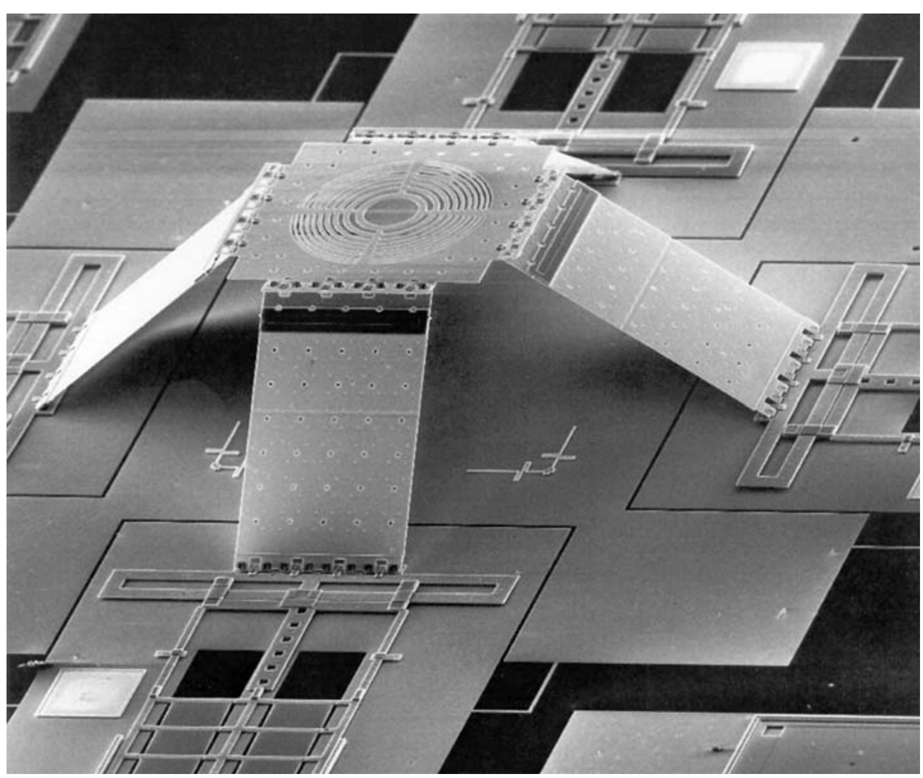
The Electromagnetics Laboratories involve the disciplines of microwaves, millimeter waves, wireless electronics, and electromechanics. Students enrolled in microwave laboratory courses, such as Electrical Engineering 164AL and 164BL, special projects classes such as Electrical Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: (1) integrated microwave circuits and antennas, (2) integrated millimeter wave circuits and antennas, (3) numerical visualization of electromagnetic waves, (4) electromagnetic scattering and radar cross-section measurements, and (5) antenna near field and diagnostics measurements.

Nanoelectronics Research Facility

The state-of-the-art Nanoelectronics Research Facility for graduate research and teaching as well as the undergraduate microelectronics teaching laboratory are housed in an 8,500-square-foot class 100/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 under-



Microlens with integrated XYZ micropositioning stage made by microelectromechanical systems technology standing 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 terrawatt (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 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.

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

Frank M.C. 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

Harold R. Fetterman, Ph.D. (Cornell, 1968)
Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state millimeter wave structures and systems, biomedical applications of lasers

Michael P. Fitz, Ph.D. (USC, 1989)
Physical layer communication theory and implementation with applications in wireless systems

* Also Professor of Mathematics

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 technology, biologic feedback control mechanisms

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

Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)
Operations research, mathematical programming, nonconvex programming, applications of mathematical programming to engineering and engineering/economic systems

Rajeev Jain, Ph.D. (Katholieke U., Leuven, Belgium, 1985)
Design of digital communications and digital signal processing circuits and systems

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

Chandrashekhar J. Joshi, Ph.D. (Hull U., England, 1978)
Laser fusion, laser acceleration of particles, nonlinear optics, high-power lasers, plasma physics

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

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

Nhan Levan, Ph.D. (Monash U., Australia, 1966)
Control systems, stability and stabilizability, errors in dynamic systems, signal analysis, wavelets, theory and applications

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

Warren B. Mori, Ph.D. (UCLA, 1987)
Laser and charged particle beam-plasma interactions, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics

Dee-Son Pan, Ph.D. (Cal Tech, 1977)
New semiconductor devices for millimeter and RF power generation and amplification, transport in small geometry semiconductor devices, generic device modeling

†C. Kumar N. Patel, Ph.D. (Stanford, 1961)
Quantum electronics; non-linear 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

† Also Professor of Physics

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

Vwani 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 nano-electronics and molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory

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

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

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

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

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

Lieven Vandenberghe, Ph.D. (Katholieke U., Leuven, Belgium, 1992)
Optimization in engineering and applications in systems and control, circuit design, and signal processing

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

Chand R. Viswanathan, Ph.D. (UCLA, 1964)
Semiconductor electronics: VLSI devices and technology, thin oxides; reliability and failure physics of MOS devices; process-induced damage, low-frequency noise

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

Paul K.C. Wang, Ph.D. (UC Berkeley, 1960)
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

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.S. Woo, Ph.D. (Stanford, 1987)
Solid-state technology, CMOS and bipolar device/circuit optimization, novel device design, modeling of integrated circuits, VLSI fabrication

Eli Yablonovitch, Ph.D. (Harvard, 1972)
Optoelectronics, high-speed optical communications, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication

Kung Yao, Ph.D. (Princeton, 1965)
Communication theory, signal and array processing, sensor system, wireless communication systems, VLSI and systolic algorithms

Professors Emeriti

Frederick G. Allen, Ph.D. (Harvard, 1956)
Semiconductor physics, solid-state devices, surface physics

Francis F. Chen, Ph.D. (Harvard, 1954)
Radiofrequency plasma sources and diagnostics for semiconductor processing

Robert S. Elliott, Ph.D. (Illinois, 1952)
Electromagnetics

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

*Donald M. Wiberg, Ph.D. (Cal Tech, 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

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

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

Fernando G. Paganini, Ph.D. (Cal Tech, 1996)
Robust and optimal control, distributed control, control communication networks, power systems

Ingrid M. Verbauwhede, Ph.D. (Katholieke U., Leuven, Belgium, 1991)
Embedded systems, VLSI, architecture and circuit design and design methodologies for applications in security, wireless communications and signal processing

Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and detection

C.-K. Ken Yang, Ph.D. (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design

* Also Professor Emeritus of Anesthesiology

Assistant Professors

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

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

Sudhakar Pamarti, Ph.D. (UC San Diego, 2003)
Mixed-signal IC design, signal processing and communication theory

Michaela van der Scharr, 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

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, microwave integrated circuits

Adjunct Professors

Nicolaos G. Alexopoulos, Ph.D. (Michigan, 1968)
Integrated microwave and millimeter wave circuits and antennas, substrate materials and thin films, electromagnetic theory

Elliott R. Brown, Ph.D. (Cal Tech, 1985)
Ultrafast electronics and optoelectronics, microwave and power electronics, infrared and RF sensors and materials, biomedical and remote chem-bio sensors

Giorgio Franceschetti, Ph.D. (Higher Institute of Telecommunications, Rome, 1961)
Electromagnetic radiation and scattering, nonlinear propagation, synthetic aperture radar processing

Brian H. Kolner, Ph.D. (Stanford, 1985)
Ultrashort light pulse generation and detection, compact femtosecond sources, mode-locking and pulse compression, noninvasive characterization of high-speed semiconductor devices and circuits

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

Ming C. Wu, Ph.D. (UC Berkeley, 1988)
MEMS, micro-opto-electromechanical systems (MOEMS), optoelectronics, RF photonics, optical communications

Adjunct Associate Professors

Bijan Houshmand, Ph.D., (Illinois, Urbana, 1990)
Computational electromagnetics, microwave imaging, and remote sensing

William H. Mangione-Smith, Ph.D. (Michigan, 1992)
Computer architecture and microarchitecture design and evaluation, compiler technology for low power and high performance

Adjunct Assistant Professors

Charles Chien, Ph.D. (UCLA, 1995)
End to end radio systems for high-speed adaptive wireless multimedia communications, multiband adaptive radio front-end architecture, adaptive spread-spectrum transceiver architectures, and

digital baseband transceiver integrated circuits for low-power high-performance applications

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

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 an engineering orientation. Emphasis on mathematical tools necessary to express and solve Maxwell equations. Relation of these concepts to waves propagating in free space, including dielectrics and optical systems. Letter grading.
Mr. Fetterman, Mr. Itoh (F,W,Sp)

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. Mr. Fetterman, Mr. Pan (F,W,Sp)

10. Circuit Analysis I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 1 or Physics 1C, Mathematics 33A, 33B. Introduction to linear circuit analysis. Resistive circuits, Kirchhoff laws, operational amplifiers, node and loop analysis, Thevenin and Norton theorem, capacitors and inductors, duality, first-order circuits, step response, second-order circuits, natural response, forced response. Letter grading.
Mr. Daneshrad, Mr. Pan (F,W,Sp)

M16. Logic Design of Digital Systems. (4) (Same as Computer Science M51A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Physics 1C. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading. Mr. Srivastava, Ms. Verbauwhede (F,W,Sp)

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

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

Upper Division Courses

100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 1 or Physics 1C, Mathematics 33A, 33B. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state circuit behavior, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.
Mr. Razavi (F,Sp)

101. Engineering Electromagnetics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 1 or Physics 1C, Mathematics 32A and 32B, or 33A and 33B. Electromagnetic field concepts, waves and phasors, transmission lines and Smith chart, transient responses, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading. Mr. Rahmat-Samii (F,W)

102. Systems and Signals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 1 or Physics 1C, 103 (may be taken concurrently), Mathematics 33A, 33B. Elements of differential equations, first- and second-order equations, variation of parameters method and method of undetermined coefficients, existence and uniqueness. Systems: input/output description, linearity, time-invariance, and causality. Impulse response functions, superposition and convolution integrals. Laplace transforms and system functions. Fourier series and transforms. Frequency responses, responses of systems to periodic signals. Sampling theorem. Letter grading.
Mr. Levan, Mr. Paganini (F,W,Sp)

103. Applied Numerical Computing. (4) Lecture, three hours; discussion, one hour; outside study, 11 hours. Requisites: Civil Engineering 15 or Computer Science 31 or Mechanical and Aerospace Engineering 20, Mathematics 33A, 33B. Introduction to numerical analysis and computing techniques: root finding, matrix computations for systems of linear equations, systems of nonlinear equations, numerical methods for ordinary differential equations, least squares, eigenvalue/eigenvector problem, applications to engineering problems. Letter grading.
Mr. Jacobsen (F,W,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 power, network functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis. Letter grading.
Mr. Daneshrad (F,W,Sp)

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

113. Digital Signal Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102. Relationship between continuous-time and discrete-time signals. Z-transform. Discrete Fourier transform. Fast Fourier transform. Structures for digital filtering. Introduction to digital filter design techniques. Letter grading.
Ms. Alwan, Mr. Sayed (F,Sp)

113D. Digital Signal Processing Design. (4) (Formerly numbered 113L.) 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 systems for communications, speech, audio, or video using DSP chip. Letter grading.
Mr. Jain, Ms. Verbauwhede (F,Sp)

114D. Speech and Image Processing Systems Design. (4) 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 techniques for image enhancement, filtering, and transformation in second half. Lectures supplemented by laboratory implementation of speech and image processing tasks. Letter grading.
Ms. Alwan, Mr. Villasenor (Sp)

115A. Analog Electronic Circuits I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 110. Review of physics and operation of diodes and bipolar and MOS transistors. Equivalent circuits and models of semiconductor devices. Analysis and design of single-stage amplifiers. DC biasing circuits. Small-signal analysis. Operational amplifier systems. Letter grading.
Mr. C.K. Yang (F,W,Sp)

115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. Requisites: courses 110L, 115A. Experimental determination of device characteristics, resistive diode circuits, single-stage amplifiers, compound transistor stages, effect of feedback on single-stage amplifiers. Letter grading. Mr. C.K. Yang (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. Feedback and its properties. Stability issues and frequency compensation. Letter grading. Mr. Abidi, Mr. Razavi (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 multiloop feedback amplifiers. Introduction to thick film hybrid techniques. Construction of amplifier using hybrid thick film techniques. Letter grading. Mr. Abidi (W,Sp)

115C. Digital Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 115A, Computer Science M51A. Recommended: course 115B. Transistor-level digital circuit analysis and design. Modern logic families (TTL, ECL, NMOS, CMOS), integrated circuit (IC) layout, MSI digital circuits (flipflops, registers, counters, PLAs, etc.), computer-aided simulation of digital circuits. Letter grading.
Ms. Verbauwhede (F,W,Sp)

115D. Design Studies in Electronic Circuits. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 115B, 115C. Applications of distributed circuits. Operational amplifier applications and limitations. Power amplifiers. Feedback and stability. Precision analog circuits. Analysis and design of operational amplifiers. Noise in electronic circuits. Design of oscillators, phase-locked loops, and frequency synthesizers. Introduction to design of analog-to-digital and digital-to-analog converters. Letter grading. Mr. Abidi (Sp)

M116C. Computer Systems Architecture. (4) (Same as Computer Science M151B.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course M16 or Computer Science M51A, Computer Science 33. Recommended: course M116L or Computer Science M152A, Computer Science 111. 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. Roychowdhury (F,W,Sp)

M116D. Digital Design Project Laboratory. (4) (Same as Computer Science M152B.) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisite: course M116C or Computer Science M151B. Design and implementation of complex digital subsystems using field-programmable gate arrays (e.g., processors, special-purpose processors, device controllers, and input/output interfaces). Students work in teams to develop and implement designs and to document and give oral presentations of their work. Letter grading.
Mr. Mangione-Smith (F,W,Sp)

M116L. Introductory Digital Design Laboratory. (2) (Same as Computer Science M152A.) Laboratory, four hours; outside study, two hours. Requisite: 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 circuits using programmed array logic, design projects. Letter grading. Mr. Srivastava (F,W,Sp)

M117. Computer Networks: Physical Layer. (6) (Same as Computer Science M117.) Lecture, four hours; discussion, four hours; outside study, 10 hours. Not open to students with credit for course M171L. Introduction to fundamental data communication concepts underlying and supporting modern networks, with focus on physical and media access layers of network protocol stack. Systems include high-speed LANs (e.g., fast and giga Ethernet), optical DWDM (dense wavelength division multiplexing), time division SONET networks, wireless LANs (IEEE802.11), and ad hoc wireless and personal area networks (e.g., Bluetooth). Experimental laboratory sessions included. Letter grading. Mr. Gerla (W)

118D. VLSI System Design. (4) (Formerly numbered 116B.) Lecture, three hours; discussion, one hour; laboratory, four hours; outside study, four hours. Requisites: courses M16, 115C, and 113D or M116D. Familiarity with digital circuit, logic design, and computer architecture assumed. VLSI design from systems perspective, with focus on (1) core VLSI architecture concepts such as datapath design, clocking, power, speed, area trade-off, input/output, packaging, etc. and (2) behavioral, register-transfer, logic, and physical-level structured VLSI design using CAD tools and hardware description languages such as VHDL. Letter grading. Mr. Srivastava (W)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to principles of operation of bipolar and MOS transistors, equivalent circuits, high-frequency behavior, voltage limitations. Letter grading. Mr. K.L. Wang, Mr. Woo (W,Sp)

122L. Semiconductor Devices Laboratory. (4) (Formerly numbered 122AL.) 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 junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Letter grading. Mr. Chang, Mr. Fetterman (W,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. Fetterman, Mr. Yablonovitch (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. Letter grading. Mr. Brown, Mr. Stafsudd (W)

124. Semiconductor Physical Electronics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 123A. Band structure of semiconductors, experimental probes of basic band structure parameters, statistics of carriers, carrier transport properties at low fields, excess carrier transport properties, carrier recombination mechanisms, heterojunction properties. Letter grading. Mr. Brown, Mr. Pan (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 processing and device design. Device structure optimization tool is based on PISCES; process integration tool is based on SUPREM. Course familiarizes students with the tools. Using CAD tools, a CMOS process integration to be designed. Letter grading.
Mr. Woo (Sp)

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 and vectors, distributions and densities, moments, characteristic functions, and limit theorems. Applications to communication, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading.
Mr. Roychowdhury (F,W)

131B. Introduction to Stochastic Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Introduction to concepts of stochastic processes, emphasizing continuous- and discrete-time stationary processes, correlation function and spectral density, linear transformation, and mean-square estimation. Applications to communication, control, and signal processing. Introduction to computer simulation and analysis of stochastic processes. Letter grading.
Mr. Balakrishnan, Mr. Yao (Sp)

132A. Introduction to Communication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102, 113, 131A. Properties of signals and noise. Baseband pulse and digital signaling. Bandpass signaling techniques. Communication systems: digital transmission, frequency-division multiplexing and telephone systems, satellite communication systems. Performance of communication systems in presence of noise. Letter grading. Mr. Fitz, Mr. Wesel (W,Sp)

132B. Data Communications and Telecommunication Networks. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Layered communications architectures. Queueing system modeling and analysis. Error control, flow and congestion control. Packet switching, circuit switching, and routing. Network performance analysis and design. Multiple-access communications: TDMA, FDMA, polling, random access. Local, metropolitan, wide area, integrated services networks. Letter grading. Mr. Rubin (W)

136. Introduction to Engineering Optimization Techniques. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 103, Mathematics 32A, 33A. Introduction to optimization techniques for engineering and science students. Minimization of unconstrained functions of several variables: steepest descent, Newton/Raphson, conjugate gradient, and quasi-Newton methods. Rates of convergence. Methods for constrained minimization: introduction to linear programming and gradient projection methods. Lagrangian methods. Students expected to use SEASnet computers. Letter grading.
Mr. Jacobsen, Mr. Vandenberghe (W)

141. Principles of Feedback Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102. Mathematical modeling of physical control systems in form of differential equations and transfer functions. Design problems, system performance indices of feedback control systems via classical techniques, root-locus and frequency-domain methods. Computer-aided solution of design problems from real world. Letter grading.
Mr. Levan, Mr. P.K.C. Wang (F,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. Levan, Mr. P.K.C. Wang (W)

M150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Biomedical Engineering M150 and Mechanical and Aerospace Engineering M180.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course M150L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Letter grading. Mr. Judy (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, multiplexing and sensor networks, physical and biomedical sensors. Design and implementation of optical gyroscope, computer interfacing, and signal processing. Letter grading.
Mr. Jalali (Sp, alternate years)

M150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Biomedical Engineering M150L and Mechanical and Aerospace Engineering M180L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Corequisite: course M150. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Letter grading. Mr. Judy (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, phase and group velocity, radiation and antennas. Letter grading.
Mr. Rahmat-Samii (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. Array synthesis. Adaptive arrays. Friis transmission formula, radar equations. Cell-site and mobile antennas, bandwidth budget. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Rahmat-Samii (Sp)

163A. Introductory Microwave Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 161. Transmission lines description of waveguides, impedance transformers, power dividers, directional couplers, filters, hybrid junctions, nonreciprocal devices. Letter grading. Mr. Itoh (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 models, noise model, large signal model, loadpull method, parameter extraction technique. Letter grading. Mr. Chang, Mr. Pan (Sp)

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. Itoh (F)

164D. Microwave Wireless Design. (4) (Formerly numbered 164DL.) 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) knowledge and skills required in wireless integrated circuit characterization and implementation. Letter grading. Mr. Chang (Sp)

164L. Microwave Wireless Laboratory. (2) (Formerly numbered 164AL.) 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, wavemeters, slotted lines, directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip and coaxial systems. Letter grading. Mr. Itoh, Mr. Jalali (W)

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, Computer Science 171. Limited to seniors. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem and terminal characteristics, and interfaces. Letter grading. Mr. Fetterman (Sp)

172. Introduction to Lasers and Quantum Electronics. (4) 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. Joshi, Mr. Stafsudd (F,Sp)

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. Joshi, Mr. Stafsudd (F)

173. Photonic Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 101. Introduction to basic principles of photonic devices. Topics include crystal optics, dielectric optical waveguides, waveguide couplers, electro-optic devices, magneto-optic devices, acousto-optic devices, second-harmonic generation, optical Kerr effect, optical switching devices. Letter grading. Mr. Liu, Mr. Stafsudd (W)

173DL. Photonics and Communication Design Laboratory. (4) Laboratory, four hours; outside study, eight hours. Requisite: course 102. Recommended: course 132A. Introduction to measurement of basic photonic devices, including LEDs, lasers, detectors, and amplifiers; fiber-optic fundamentals and measurement of fiber systems. Modulation techniques, including A.M., F.M., phase and suppressed carrier methods. Letter grading. Mr. Stafsudd, Mr. Wu (W)

174. Semiconductor Optoelectronics. (4) Lecture, three hours; discussion, one hour; outside study, eight 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. Mr. Fetterman, Mr. Wu (Sp)

175. Fourier Optics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: courses 102, 161. Two-dimensional linear systems and Fourier transforms. Foundation of diffraction theory. Analysis of optical imaging systems. Spatial filtering and optical information processing. Wavefront reconstruction and holography. Letter grading. Mr. Stafsudd

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. Fetterman (W, alternate years)

180D. Systems Design. (4) (Formerly numbered 190D.) 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. Different project to be assigned yearly in which student teams create high-performance designs that manage trade-offs among subsystems. Letter grading. Mr. Kaiser, Mr. Pottie (F,Sp)

M185. 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. Joshi, Mr. Mori (F, even years)

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

194. Research Group Seminars: Electrical Engineering. (2 to 4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Letter grading.

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

Graduate Courses

201A. VLSI Architectures and Design Methodologies. (4) Lecture, four hours; outside study, eight hours. Requisite: course M216A or Computer Science M258A. In-depth study of VLSI architectures and VLSI design methodologies for variety of applications in signal processing, communications, networking, embedded systems, etc. VLSI architectures choices range from ASICs, full custom approach, and special purpose processors to general purpose microprocessors. VLSI design methodologies take design specifications to implementation with aid of modern computer-aided design tools. Letter grading. Ms. Verbauwhede (Sp)

201C. Modeling of VLSI Circuits and Systems. (4) Lecture, four hours. Requisite: course 115C. Detailed study of VLSI circuit and system models considering performance, signal integrity, power and thermal effects, reliability, and manufacturability. Discussion of principles of modeling and optimization codevelopment. Letter grading. Mr. He (Sp)

M202A. Embedded Systems. (4) (Formerly numbered 202A.) (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 design of embedded systems. Topics include hardware and software platforms for embedded systems, techniques for modeling and specification of system behavior, software organization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery and energy-aware system design, timing synchronization, fault tolerance and debugging, 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) (Formerly numbered 206A.) (Same as Computer Science M213B.) 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. Interdisciplinary course with focus on study of distributed embedded systems concepts needed to realize systems such as wireless sensor and actuator networks for monitoring and control of physical world. Topics include network self-configuration with localization 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 collaborative 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. S/U or letter grading. Mr. Srivastava (Sp)

204A. Advanced Compilers. (4) Lecture, four hours; outside study, eight hours. Requisites: Computer Science 132, 251A. Designed for graduate computer science and electrical engineering students. Efficient allocating of shared resources (buses, function units, register files) is one of most important areas of research in modern computer architecture and compilation research. Consideration of instruction selection and scheduling, register assignment, and low-level transformation in context of concurrent microarchitecture (e.g., VLIW, superscalar, and most DSP). Topics include mapping to specific introprocessor communications buses, making effective use of hardware caches, and targeting special-purpose function units. Letter grading. Mr. Mangione-Smith (W)

208A. Analytical Methods of Engineering I. (4) (Formerly numbered M208A.) Lecture, four hours; outside study, eight hours. Limited to graduate students. Application of techniques of linear algebra to engineering problems. Vector spaces: scalar products, Cauchy/Schwarz inequality. Gram/Schmidt orthogonalization. Matrices as linear transformations: eigenvalues and spectrum. Self-adjoint and covariance matrices. Square root and factorization, Cholesky decomposition. Determinants, Cayley/Hamilton theorem. Minimal polynomials, Bezout theorem. Polar and singular value decomposition. Sequences, convergence, and matrix exponential. Applications to problems in signal processing, communications, and control. Letter grading. Mr. Balakrishnan (F,W)

208B. Analytical Methods of Engineering II. (4) (Formerly numbered M208B.) Lecture, four hours; outside study, eight hours. Requisite: course 208A. Application of modern mathematical methods to engineering problems. Review of spectral theory. Green's functions and eigenvalue problems for second-order ordinary differential equations and their adjoints. Discrete and continuous spectra for ordinary and partial differential equations. Initial and boundary value problems. Letter grading. Mr. Levan (W,Sp)

208C. Semigroups of Linear Operators and Applications. (4) Lecture, four hours; outside study, eight hours. Requisite: course M208B. Semigroups of linear operators over Hilbert spaces. Generator and resolvent, generation theorems, Laplace inversion formula. Dissipative operators and contraction semigroups. Analytic semigroups and spectral representation. Semigroups with compact resolvents. Parabolic and hyperbolic systems. Controllability and stabilizability. Applications. Letter grading.
Mr. Balakrishnan, Mr. Levan (Sp)

209S. Special Topics in Embedded Computing Systems. (4) Lecture, four hours; outside study, eight hours. Current topics in embedded computing systems, including but not limited to processor and system architecture, real-time, low-power design. S/U or letter grading. Mr. Mangione-Smith

210A. Adaptive Filtering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131B, Mathematics 115A. Optimal filtering and estimation, Wiener filters, linear prediction. Steepest descent and stochastic gradient algorithms. Frequency-domain adaptive filters. Method of least squares, recursive least squares, fast fixed-order and order-recursive (lattice) filters. Misadjustment, convergence, and tracking analyses, stability issues, finite precision effects. Connections with Kalman filtering. Nonlinear adaptive filters. Letter grading. Mr. Sayed (W)

210B. Optimal Linear Estimation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131B, 210A, Mathematics 115A. Unified treatment of fundamental concepts and basic notions in adaptive filtering, Wiener filtering, Kalman filtering, and H_oo filtering. Emphasis on geometric, equivalence, and duality arguments. Development of array methods and fast algorithms. Discussion of practical issues. Examples of applications from fields of signal processing, communications, biomedical engineering, finance, and control. Letter grading.
Mr. Sayed (Sp)

211A. Digital Image Processing I. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Preparation: computer programming experience. Requisite: course 113. Fundamentals of digital image processing theory and 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. Requisite: course 211A. Advanced digital image processing theory and techniques. Topics include modeling, restoration, still-frame and video image compression, tomographic imaging, and multi-resolution analysis using wavelet transforms. Letter grading. Mr. Villasenor

212A. Theory and Design of Digital Filters. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 113. Approximation of filter specifications. Use of design charts. Structures for recursive digital filters. FIR filter design techniques. Comparison of IIR and FIR structures. Implementation of digital filters. Limit cycles. Overflow oscillations. Discrete random signals. Wave digital filters. Letter grading. Mr. Willson (F)

212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems; polyphase representation; multistage implementations; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; paraunitary filter banks; wavelet transform and its relation to multirate filter banks. Letter grading. Mr. Wilson (W)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 212A, M216A. Digital filter design and optimization tools, architectures for digital signal processing circuits; integrated circuit modules for digital signal processing; programmable signal processors; CAD tools and cell libraries for application-specific integrated circuit design; case studies of speech and image processing circuits. Letter grading. Mr. Jain (Sp)

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 M214A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and machine. Physiology and psychoacoustics of human perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired. Letter grading.
Ms. Alwan (Sp, 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 bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and discrete-time circuits, bandgap references. Letter grading. Mr. Razavi (F)

215B. Advanced Digital Integrated Circuits. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 115C, M216A. Analysis and comparison of modern logic families (CMOS, bipolar, BiCMOS, GaAs). MSI digital circuits (flipflops, registers, counters, PLAs). VLSI memories (ROM, RAM, CCD, bubble memories, EPROM, EEPROM) and VLSI systems. Letter grading. Ms. Verbauwhede (W or Sp)

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, communications background, transceiver architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading. Mr. Razavi (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 architectures, D/A conversion techniques, A/D converter architectures, building blocks, precision techniques, discrete- and continuous-time filters. Letter grading.
Mr. Abidi (Sp)

215E. Signaling and Synchronization. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 215A, M216A. Analysis and design of circuits for synchronization and communication for VLSI systems. Use of both 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. C.K. Yang (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. Requisites: courses M16 or Computer Science M51A, and 115A. Recommended: course 115C. LSI/VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on a chip. Letter grading.
Mr. C.K. Yang (F)

M216B-M216C. LSI in Computer System Design. (4-4) (Same as Computer Science M258B-M258C.) Lecture, four hours; laboratory, four hours. Requisite: course M216A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. In Progress (M216B) and S/U or letter (M216C) grading.
Mr. Jain, Mr. Mangione-Smith

M217. Biomedical Imaging. (4) (Same as Biomedical Engineering M217.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, positron emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, image reconstruction algorithms, system configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. Letter grading. Mr. Grundfest (Sp)

219A. Special Topics in Circuits and Signal Processing. (4) Lecture, three hours; outside study, nine hours. Advanced treatment of topics selected from research areas in circuit theory, integrated circuits, or signal processing. Letter grading.
Mr. Villasenor, Mr. Yang

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

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

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

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

223. Solid-State Electronics I. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 124, 270. Energy band theory, electronic band structure of various elementary, compound, and alloy semiconductors, defects in semiconductors. Recombination mechanisms, transport properties. Letter grading. Mr. Fetterman, Mr. Pan (F)

224. Solid-State Electronics II. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Techniques to solve Boltzmann transport equation, various scattering mechanisms in semiconductors, high field transport properties in semiconductors, Monte Carlo method in transport. Optical properties. Letter grading.
Mr. Pan, Mr. Staffsudd (Sp, alternate years)

225. Physics of Semiconductor Nanostructures and Devices. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods for circulating electronics 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. Mr. K.L. Wang (Sp, alternate years)

229. Seminar: Advanced Topics in Solid-State Electronics. (4) Seminar, four hours; outside study, eight hours. Requisites: courses 223, 224. Current research areas, such as radiation effects in semiconductor devices, diffusion in semiconductors, optical and microwave semiconductor devices, nonlinear optics, and electron emission. Letter grading.

229S. Advanced Electrical Engineering Seminar. (2) Seminar, two hours; outside study, six hours. Preparation: successful completion of Ph.D. major field examination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on a tutorial topic and on a research topic in their dissertation area. May be repeated for credit. S/U grading. (F,W,Sp)

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 characterizations by analytical and simulation methods; mean square (MS) and maximum likelihood (ML) estimations and algorithms; detection under ML, Bayes, and Neyman/Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Letter grading. Mr. Yao (F)

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

230C. Algorithms and Processing in Communication and Radar. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230A. Concepts and implementations of digital signal processing algorithms in communication and radar systems. Optimum dynamic range scaling for random data. Algorithms for fast convolution and transform. Spectral estimation algorithms. Parallel processing, VLSI algorithms, and systolic arrays. Letter grading.
Mr. Yao (W)

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

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

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Fundamentals of error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading. Mr. Wesel (Sp)

232A. Stochastic Modeling with Applications to Telecommunication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Introduction to stochastic processes 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. Mr. Fitz, Mr. Wesel (F)

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

232C. Telecommunication Architecture and Networks. (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 system models. Queueing networks; network protocol architectures; error control; routing, flow, and access control. Applications to local-area, packet-radio, satellite, and computer communication networks. Letter grading. Mr. Rubin (Sp)

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

232E. Graphs and Network Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 136. Solution to analysis and synthesis problems which 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. Mr. Roychowdhury, Mr. Rubin (W,Sp)

233A. Wireless Communication Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230B. Discussion of theory of physical layer and medium access design for wireless communications. Topics include wireless signal propagation and channel modeling, information theoretic studies of wireless models, performance analysis, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access schemes. Letter grading. Mr. Fitz

233B. Wireless Communications Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230B. Various aspects of physical layer and medium access design for wireless communications systems. Topics include wireless signal propagation and channel modeling, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access schemes, transceiver design and effects of nonideal components, hardware partitioning issues. Case study highlights system level trade-offs. Letter grading.
Mr. Daneshrad (Sp)

236A. Linear Programming. (4) Lecture, four hours; outside study, eight hours. Requisite: Mathematics 115A or equivalent knowledge of linear algebra. Basic graduate course in linear optimization. Geometry of linear programming. Duality. Simplex method. Interior-point methods. Decomposition and large-scale linear programming. Quadratic programming and complementary pivot theory. Engineering applications. Introduction to integer linear programming and computational complexity theory. Letter grading.
Mr. Jacobsen, Mr. Vandenberghe (F)

236B. Nonlinear Programming. (4) Lecture, four hours; outside study, eight hours. Requisite: course 236A. Basic graduate course in nonlinear programming. Convex sets and functions. Engineering applications and convex optimization. Lagrange duality, optimality conditions, and theorems of alternatives. Unconstrained minimization methods. Convex optimization methods (interior-point methods, cutting-plane methods, ellipsoid algorithm). Lagrange multiplier methods and sequential quadratic programming. Letter grading. Mr. Jacobsen, Mr. Vandenberghe (W)

236C. Optimization Methods for Large-Scale Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 236B. Theory and computational procedures for decomposing large-scale optimization problems: cutting-plane methods, column generation, decomposition algorithms. Techniques for global continuous optimization: branch-and-bound methods, reverse convex programming, bilinear and biconvex optimization, genetic algorithms, simulated annealing. Introduction to combinatorial optimization. Letter grading. Mr. Roychowdhury (Sp)

M237. Dynamic Programming. (4) (Formerly numbered 237.) (Same as Mechanical and Aerospace Engineering M276.) Lecture, four hours; outside study, eight hours. Recommended requisite: course 232A or 236A or 236B. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. Mr. Jacobsen, Mr. Vandenberghe (Sp)

239AS. Topics in Communication. (4) Lecture, four hours; outside study, eight hours. Topics in one or more special aspects of communication systems, such as phase-coherent communication systems, optical channels, time-varying channels, feedback channels, broadcast channels, networks, coding and decoding techniques. May be repeated for credit with topic change. Letter grading.

239BS. Topics in Operations Research. (4) Lecture, four hours; outside study, eight hours. Treatment of one or more selected topics from areas such as integer programming; combinatorial optimization; network synthesis; scheduling, routing, location, and design problems; implementation considerations for mathematical programming algorithms; stochastic programming; applications in engineering, computer science, economics. May be repeated for credit with topic change. Letter grading.

M240A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A 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. Paganini (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. Relationships to classical control system design. Letter grading. Mr. Levan (W)

M240C. Optimal Control. (4) (Same as Chemical Engineering M280C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisite: course 240B. 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. Mr. P.K.C. Wang (Sp)

241A. Stochastic Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131B. Random process models: basic concepts, properties. Stationary random processes: covariance and spectrum. Response of linear systems to random inputs: discrete-time and continuous-time models. Time averages and ergodic principle. Sampling principle and interpolation. Simulation of random processes. Letter grading. Mr. Balakrishnan (F)

241B. Kalman Filtering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M240A, 241A. Review of state-space theory: Kalman signal generation model. Statistical estimation theory: maximum likelihood principle, optimum mean square estimation, conditional expectation, Wiener/Hopg equation, Gaussian signals and Gram/Schmidt orthogonalization, factorization, maximum unconditional likelihood. Kalman filter: basic theory, error propagation/steady state convergence theory, examples, applications to system parameter identification, Kalman filtering software. Kalman smoother algorithm. Nonlinear extensions, likelihood ratios for Gaussian signal. Letter grading. Mr. Balakrishnan (W)

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; feedforward control and servomechanisms, extensions to nonlinear systems; applications to interception guidance, gust alleviation. Letter grading.
Mr. Balakrishnan (Sp)

M242A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Mechanical and Aerospace Engineering M272A.) Lecture, four hours; outside study, eight hours. Requisite: course M240A or Chemical Engineering M280A 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. Liapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading. Mr. P.K.C. Wang (Sp)

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 performance 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. Paganini (Sp)

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

249S. Topics in Control. (4) Seminar, four hours; outside study, eight hours. Thorough treatment of one or more aspects of control theory and applications, such as computational methods for optimal control; stability of distributed systems; identification; adaptive control; nonlinear filtering; differential games; applications to flight control, nuclear reactors, process control, biomedical problems. May be repeated for credit with topic change. Letter grading.

M250A. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Biomedical Engineering M250A and Mechanical and Aerospace Engineering M280.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M150L. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. Judy (W)

M250B. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Biomedical Engineering M250B and Mechanical and Aerospace Engineering M282.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M250A. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading.
Mr. Wu (Sp)

259S. Seminar: Microelectromechanical Systems (MEMS). (2) Seminar, two hours; outside study, four hours. Seminar on microelectromechanical systems (MEMS). Letter grading. Mr. Judy

260A-260B. Advanced Engineering Electrodynamics. (4-4) Lecture, four hours; outside study, eight hours. Requisites: courses 161, 162A. Advanced treatment of concepts in electrodynamics and their applications to modern engineering problems. Waves in anisotropic, inhomogeneous, and dispersive media. Guided waves in bounded and unbounded regions. Radiation and diffraction, including optical phenomena. Partially coherent waves, statistical media. Letter grading.
Mr. Rahmat-Samii (F, 260A; W, 260B)

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

262. Antenna Theory and Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 162A. Antenna patterns. Sum and difference patterns. Optimum designs for rectangular and circular apertures. Arbitrary side lobe topography. Discrete arrays. Mutual coupling. Design of feeding networks. Letter grading. Mr. Rahmat-Samii (F, even years)

263. Reflector Antennas Synthesis, Analysis, and Measurement. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 260A, 260B. Reflector pattern analysis techniques. Single and multireflector antenna configurations. Reflector synthesis techniques. Reflector feeds. Reflector tolerance studies, including systematic and random errors. Array-fed reflector antennas. Near-field measurement techniques. Compact range concepts. Microwave diagnostic techniques. Modern satellite and ground antenna applications. Letter grading.
Mr. Rahmat-Samii (Sp, alternate years)

266. Computational Methods for Electromagnetics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 162A, 163A. Computational techniques for partial differential and integral equations: finite-difference, finite-element, method of moments. Applications include transmission lines, resonators, integrated circuits, solid-state device modeling, electromagnetic scattering, and antennas. Letter grading. 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 physics, and nonlinear optics. Topics include eigenfunction expansions, observables, Schrödinger equation, uncertainty principle, central force problems, Hilbert spaces, WKB approximation, matrix mechanics, density matrix formalism, and radiation theory. Letter grading. Mr. Stafsudd (F)

271. Classical Laser Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 172. Microscopic and macroscopic laser phenomena and propagation of optical pulses using classical formalism. Letter grading. Mr. Joshi (W)

272. Dynamics of Lasers. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271. Ultrashort laser pulse characteristics, generation, and measurement. Gain switching, Q switching, cavity dumping, active and passive mode locking. Pulse compression and soliton pulse formation. Nonlinear pulse generation: soliton laser, additive-pulse mode locking, and parametric oscillators. Pulse measurement techniques. Letter grading.
Mr. Liu (Sp, alternate years)

273. Nonlinear Optics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 172, 270. Nonlinear optical susceptibilities. Coupled-wave formulation. Crystal optics, electro-optics, and magneto-optics. Sum- and difference-frequency generation. Harmonic and parametric generation. Stimulated Raman and Brillouin scattering. Four-wave mixing and phase conjugation. Field-induced index changes and self-phase modulation. Letter grading.
Mr. Liu, Mr. Yablonovitch (W, alternate years)

274. Fiber Optic System Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 173DL 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 (Sp)

279S. Special Topics in Quantum Electronics. (4) Lecture, four hours; outside study, eight hours. Current research topics in quantum electronics, lasers, nonlinear optics, optoelectronics, ultrafast phenomena, fiber optics, and lightwave technology. May be repeated for credit. Letter grading.
Mr. Joshi, Mr. Wu (F,W,Sp)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and streaming instabilities. Application to experiments in fully and partially ionized gases. Letter grading. Mr. Joshi, Mr. Mori (W)

285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M185, and 285A or Physics 222A. Interaction of intense electromagnetic waves with plasmas: waves in inhomogeneous and bounded plasmas, nonlinear wave coupling and damping, parametric instabilities, anomalous resistivity, shock waves, echoes, laser heating. Emphasis on experimental considerations and techniques. Letter grading. Mr. Chen, Mr. Joshi (Sp)

M287. Fusion Plasma Physics and Analysis. (4) (Same as Mechanical and Aerospace Engineering M237B.) Lecture, four hours; outside study, eight hours. Requisite: course M185. Fundamentals of plasmas at thermonuclear burning conditions. Fokker/Planck equation and applications to heating by neutral beams, RF, and fusion reaction products. Bremsstrahlung, synchrotron, and atomic radiation processes. Plasma surface interactions. Fluid description of burning plasma. Dynamics, stability, and control. Applications in tokamaks, tandem mirrors, and alternate concepts. Letter grading.
Mr. Chen, Mr. Joshi (W)

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.

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate electrical engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. 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 the University. May be repeated for credit. S/U grading.
(F,W,Sp)

475C. Manufacturing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 475B. Modeling and analysis of manufacturing systems. Assembly and transfer lines. Facility layout and design. Group technology and flexible manufacturing systems. Planning and scheduling. Task management, machine setup, and operation sequencing. Manufacturing system models. Manufacturing information systems. Social, economic, environmental, and regulatory issues. Letter grading. Mr. Jacobsen (Sp)

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

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

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

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

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

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

Materials Science and Engineering

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Mark S. Goorsky, Ph.D., *Chair*
Jenn-Ming Yang, Ph.D., *Vice Chair*
Ya-Hong Xie, Ph.D., *Vice Chair*

Professors

Alan J. Ardell, Ph.D.
Russel E. Caflisch, Ph.D.
Emily C. Carter, Ph.D.
Bruce S. Dunn, Ph.D., *NSG Chair (Nippon Sheet Glass Company Professor of Materials Science)*
Nasr M. Ghoniem, Ph.D.
Mark S. Goorsky, Ph.D.
Vijay Gupta, Ph.D.
H. Thomas Hahn, Ph.D. *(Raytheon Company Professor of Manufacturing Engineering)*
Richard B. Kaner, Ph.D.
Kanji Ono, Ph.D.
Qibing Pei, Ph.D.
King-Ning Tu, Ph.D
Fred Wudl, Ph.D.
Ya-Hong Xie, Ph.D.
Jenn-Ming Yang, Ph.D.
Yang Yang, Ph.D.

Professors Emeriti

David L. Douglass, Ph.D.
William Klement, Jr., Ph.D.
John D. Mackenzie, Ph.D. *(Nippon Sheet Glass Company Professor Emeritus of Materials Science)*
Aly H. Shabaik, Ph.D.
George H. Sines, Ph.D.
Christian N.J. Wagner, Dr.rer.nat.
Alfred S. Yue, Ph.D.

Assistant Professors

Ioanna Kakoulli, D.Phil.
Vidvuds Ozolins, Ph.D.
Benjamin Wu, D.D.S., Ph.D.

Adjunct Professors

Eric P. Bescher, Ph.D.
Harry Patton Gillis, Ph.D.
John J. Gilman, Ph.D.
Marek A. Przystupa, Ph.D.

Scope

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.

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.

Materials Engineering B.S.

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.

The Major

Course requirements are as follows (182 or 183 minimum units required):

1. Five core courses: Chemical Engineering M105A (or Mechanical and Aerospace Engineering M105A), Civil and Environmental Engineering 108, Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102
2. Materials Science and Engineering 10 (2 units), 110, 110L, 120, 130, 131, 131L, 132, 140, 141L, 143A, 150, 160, 161L; Mechanical and Aerospace Engineering 181A or 182A
3. Three elective courses from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical Engineering 2, 123A, 123B, 124, Materials Science and Engineering 111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C
4. One course from Electrical Engineering 131A or Mathematics 170A or Statistics 100A, plus 8 additional units from Chemistry and Biochemistry 30A, 30AL, Materials Science and Engineering 170, 171, or by petition, upper division courses from engineering, intermediate or advanced foreign language, mathematics, or physical or life sciences. Intermediate foreign language courses may be lower division
5. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 15 or Computer Science 31; Materials Science and Engineering 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1)
6. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Electronic Materials Option

Course requirements are as follows (194 or 195 minimum units required):

1. Six core courses: Chemical Engineering M105A (or Mechanical and Aerospace Engineering M105A), Civil and Environmental Engineering 108, Electrical Engineering 10, 101, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102
2. Materials Science and Engineering 10, 110, 110L, 120 (or Electrical Engineering 2), 121, 122, 130, 131, 131L, 140; Electrical Engineering 121B, 122L, 123A, 123B, and two courses from Materials Science and Engineering 132, 150, 160; Mechanical and Aerospace Engineering 181A or 182A
3. Four elective courses from Materials Science and Engineering 111, 143A, 162, Electrical Engineering 110, 124, 131A, 172; 4 laboratory units from Materials Science and Engineering 141L, 161L, 199, Electrical Engineering 172L
4. Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31; Materials Science and Engineering 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1)
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the

"Publications" link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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

Materials Science and Engineering M.S.

Areas of Study

There are three main areas in the M.S. program: ceramics and ceramic processing, electronic and optical materials, and structural materials. Students may specialize in any one of the three areas, although most students are more interested in a broader education and select a variety of courses. Basically, students select courses that serve their interests best in regard to thesis research and job prospects.

Course Requirements

Thesis Plan. Nine courses are required, of which six must be graduate courses. The courses are to be selected from the following lists, although suitable substitutions can be made from other engineering disciplines or from chemistry and physics with the approval of the departmental graduate adviser. Two of the six graduate courses may be Materials Science and Engineering 598 (thesis research). The remaining three courses in the total course requirement may be upper division courses.

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. Three of the nine courses may be upper division courses.

Ceramics and ceramic processing: Materials Science and Engineering 111, 121, 122, 143A, 151, 161, 162, 200, 201, 244, 246A, 246D, 298.

Electronic and optical materials: Materials Science and Engineering 111, 121, 122, 143A, 151, 161, 162, 200, 201, 221, 222, 223, 244, 298.

Structural materials: Materials Science and Engineering 111, 121, 122, 143A, 151, 161, 162, 200, 201, 243A, 243C, 244, 250A, 250B, 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 M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 105D, 199.

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.

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 reviews and approves the thesis.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines

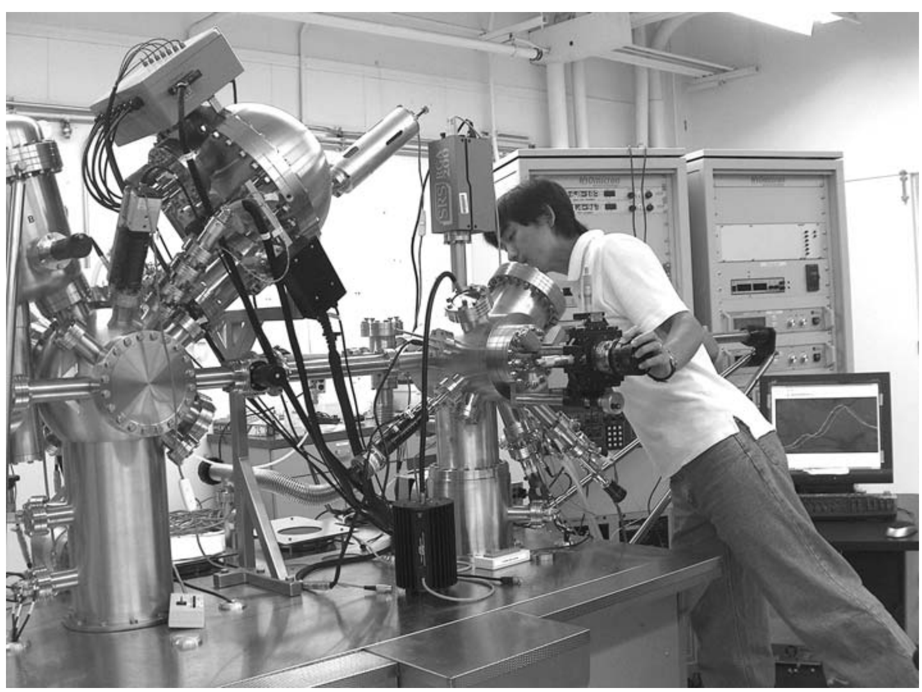
Ceramics and ceramic processing, electronic and optical materials, and structural materials.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed to satisfy the written preliminary examination requirement. In this case, a grade-point average of at least 3.33 in all courses is required, with a grade of B— or better in each course.

The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of knowledge contained in nine courses, at least six of which must be graduate courses, plus the current literature in the area of specialization. Materials Science and Engineering 599 may not be applied toward the nine-course total. The major fields named above are described in a Ph.D. major field syllabus, each of which can be obtained in the department office.

The minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses.



The X-ray Photoemission Spectrometer and UV Photoemission Spectrometer is equipped with a sample preparation chamber. The first of its kind at UCLA, it was awarded to Professor Yang Yang's laboratory through an Air Force grant.

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 which encompasses the body of knowledge in materials science equivalent to that expected of a bachelor's degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice.

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

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are "inside" members and must hold appointments at UCLA in the student's major department in HSSEAS. The "outside" member must be a UCLA faculty member outside the student's major department. Faculty members holding joint appointments with the Materials Science and Engineering 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 which 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 which include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities

Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Electron Microscopy Laboratories with a scanning transmission electron microscope (100 keV), a field emission transmission electron microscope (200 keV), and a scanning electron microscope, all equipped with a full quantitative analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes
- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Nondestructive Testing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Thin Film Deposition Laboratory
- X-Ray Diffraction Laboratory

Faculty Areas of Thesis Guidance

Professors

Alan J. Ardell, Ph.D. (Stanford, 1964)
Irradiation-induced precipitation, high-temperature deformation of solids, electron microscopy, physical metallurgy of aluminum/lithium alloys, precipitation hardening

Russel 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

Emily A. Carter, Ph.D. (Cal Tech, 1987)
Development and application of first principles, quantum mechanical and multi-scale models of materials

Bruce S. Dunn, Ph.D. (UCLA, 1974)
Solid electrolytes, electrical properties of ceramics and glasses, ceramic-metal bonding, optical materials

Nasr M. Ghoniem, Ph.D. (Wisconsin, 1977)
Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relaxation in epitaxial semiconductors and device structures, high-resolution X-ray diffraction of semiconductors, ceramics, and high-strength alloys

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

H. Thomas Hahn, Ph.D. (Pennsylvania State, 1971)
Nanocomposites, multifunctional composites, nanomechanics, rapid prototyping, information systems

Richard B. Kaner, Ph.D. (Pennsylvania, 1984)
Rapid synthesis of high-temperature materials, conducting polymers as separation membranes for enantiomers, synthesis of carbon nanoscrolls and composites

Kanji Ono, Ph.D. (Northwestern, 1964)
Mechanical behavior and nondestructive testing of structural materials, acoustic emission, dislocations and strengthening mechanisms, microstructural effects, and ultrasonics

Qibing Pei, Ph.D. (Chinese Academy of Sciences, 1990)
Electroactive polymers through molecular design and nano-engineering for electronic devices and artificial muscles

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

Fred Wudl, Ph.D. (UCLA, 1967)
Organic materials synthesis, organic electronic devices, including field-effect transistors, light-emitting devices, organic metals and superconductors, Fallerene chemistry applied to these areas

Ya-Hong Xie, Ph.D. (UCLA, 1986)
Hetero-epitaxial growth of semiconductor thin films: strained Si, self-assembled quantum dots, and other epitaxial nano-structures; nano-patterning using diblock copolymer; Si substrate impedance engineering for mixed-signal integrated circuit technologies

Jenn-Ming Yang, Ph.D. (Delaware, 1986)
Mechanical behavior of polymer, metal, and ceramic matrix composites, electronics packaging

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

Professors Emeriti

David L. Douglass, Ph.D. (Ohio State, 1958)
Oxidation and sulfidation kinetics and mechanisms, materials compatibility, defect structures, diffusion

William Klement, Jr., Ph.D. (Cal Tech, 1962)
Phase transformations in solids, high-pressure effects on solids

John D. Mackenzie, Ph.D. (Imperial C., London, 1954)
Glass science, ceramics, electrical properties of amorphous materials, materials recycling

Aly H. Shabaik, Ph.D. (UC Berkeley, 1966)
Metal forming, metal cutting, mechanical properties, friction and wear, biomaterials, manufacturing processes

George H. Sines, Ph.D. (UCLA, 1953)
Fracture of ceramics, fatigue of metals, carbon-carbon composites, failure analysis

Christian N.J. Wagner, Dr.rer.nat. (U. des Saarlandes, 1957)
X-ray and neutron diffraction; structure of liquid and amorphous alloys, and plastically deformed metals; biomaterials; thin films; residual stresses

Alfred S. Yue, Ph.D. (Purdue, 1957)
Semiconductor eutectics; electronic materials for solar cell and detector applications, solidification and crystal growth

Assistant Professors

Ioanna Kakoulli, D.Phil. (University of Oxford, 1999)
Chemical and physical properties of non-metallic archaeological materials; alteration processes in archaeological vitreous materials and pigments

Vidvuds Ozolins, Ph.D. (Kungliga Tekniska Högskolan, Stockholm, 1998)
Theory of materials, first-principles modeling of phase transformations in bulk and surface systems, vibrational and electronic properties

Benjamin Wu, Ph.D. (MIT, 1997)
Processing, characterization, and controlled delivery of biological molecules of bioerodible polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Adjunct Professors

Eric P. Bescher, Ph.D. (UCLA, 1987)
Advanced cementitious materials, sol-gel materials, organic/inorganic hybrids

Harry Patton Gillis, Ph.D. (Chicago, 1974)
Application of surface science and chemical dynamics techniques to elucidate fundamental molecular mechanisms and optimize practical processes

John J. Gilman, Ph.D. (Columbia U., 1952)
Mechanochemistry, dislocation mobility, metallic glasses, fracture phenomena, shock and deterioration fronts, research management theory

Marek A. Przystupa, Ph.D. (Michigan Tech, 1980)
Mechanical behavior of solids

Lower Division Courses

10. Freshman Seminar: New Materials. (2) (Formerly numbered 88.) Seminar, two hours; outside study, four hours. Preparation: high school chemistry and physics. Not open to students with credit for course 14. Introduction to basic concepts of materials science and new materials vital to advanced technology. Microstructural analysis and various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. Letter grading. Mr. Ono (F)

14. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, 20L, Physics 1A, 1B. General introduction to different types of materials used in engineering designs: metals, ceramics, plastics, and composites, relationship between structure (crystals and microstructure) and properties of technological materials. Illustration of their fundamental differences and their applications in engineering. Letter grading. Mr. Dunn (F,W,Sp)

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.

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

110. Introduction to Materials Characterization A (Crystal Structure and X-Ray Diffraction of Materials). (4) Lecture, three hours; laboratory, two hours. Requisite: course 14. Modern methods of materials characterization; fundamentals of crystallography, properties of X rays, X-ray diffraction; powder method, Laue method; determination of crystal structures; phase diagram determination; X-ray stress measurements; X-ray spectroscopy; design of materials characterization procedures. Letter grading. Mr. Goorsky (F)

110L. Introduction to Materials Characterization A Laboratory. (2) Laboratory, two hours; outside study, four hours. Requisite: course 14. Experimental techniques and analysis of materials through X-ray scattering techniques; powder method, lane method, crystal structure determination, and special projects. Letter grading. Mr. Goorsky (F)

111. Introduction to Materials Characterization B (Electron Microscopy). (4) Lecture, three hours; laboratory, two hours. Requisites: courses 14, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy: emissive and reflective modes; chemical analysis; electron optics of both instruments. Letter grading. Mr. Ardell (W)

120. Physics of Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 14, 110 (or Chemistry 113A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectrical properties, and p-n junctions. Letter grading. Mr. Dunn (W)

121. Materials Science of Semiconductors. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and ion-beam techniques. Heterostructures, band-gap engineering, development of new materials for optoelectronic applications. Letter grading. Mr. Dunn (Sp)

121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Corequisite: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading. Mr. Tu (W)

122. Principles of Electronic Materials Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 14. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading. Mr. Goorsky (W)

123. Electronic Packaging and Interconnection. (2) Lecture, two hours; outside study, six hours. Various electronic packaging methods and interconnection technologies. Design, fabrication, and testing of complex microelectronic components, interconnections, and assemblies. Letter grading. Mr. Tu

130. Phase Relations in Solids. (4) Lecture, four hours; outside study, eight hours. Requisites: course 14, and Chemical Engineering M105A or Mechanical and Aerospace Engineering M105A. Summary of thermodynamic laws, equilibrium criteria, solution thermodynamics, mass-action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Goorsky (F)

131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermediate phases, gas-solid reactions, design of oxidation-resistant alloys, recrystallization, and grain growth. Letter grading. Mr. Tu (W)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Corequisite: course 131. Design of heat-treating cycles and performing experiments to study interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. Mr. Tu (W)

132. Structure and Properties of Metallic Alloys. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Physical metallurgy of steels, lightweight alloys (Al and Ti), and superalloys. Strengthening mechanisms, microstructural control methods for strength and toughness improvement. Grain boundary segregation. Letter grading. Mr. Ono (Sp)

140. Materials Selection and Engineering Design. (4) (Formerly numbered 190.) Lecture, four hours; outside study, eight hours. Requisites: courses 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymeric, ceramic, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading. Mr. Przystupa (Sp)

141L. Computer Methods and Instrumentation in Materials Science. (2) (Formerly numbered 191L.) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to junior/senior Materials Science and Engineering majors. Interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading. Mr. Goorsky (W)

143A. Mechanical Behavior of Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 14. Recommended: Civil Engineering 108. Plastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocations, fracture, microstructural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. Przystupa (W)

143L. Mechanical Behavior Laboratory. (2) Laboratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Methods of characterizating mechanical behavior of various materials; elastic and plastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. Ono (W)

150. Introduction to Polymers. (4) Lecture, three hours; laboratory, two 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 polymers, polymer processing technology, plasticiation. Letter grading. Mr. J-M. Yang (W)

151. Structure and Properties of Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: at least two courses from 132, 143A, 150, 160. Requisite: course 14. Relationship between structure and mechanical properties of composite materials with fiber and particulate reinforcement. Properties of fiber, matrix, and interfaces. Selection of macrostructures and material systems. Letter grading. Mr. Ono (Sp)

160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 14, 130. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading. Mr. Dunn (F)

161. Processing of Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour. Requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting. Microstructure properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading. Mr. Dunn (W, even years)

161L. Laboratory in Ceramics. (2) Laboratory, four hours. Requisite: course 160. Recommended corequisite: course 161. Processing of common ceramics and glasses. Attainment of specific properties through process control for engineering applications. Quantitative characterization and selection of raw materials. Slip casting and extrusion of clay bodies. Sintering of powders. Glass melting and fabrication. Determination of chemical and physical properties. Letter grading. Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 14, Electrical Engineering 100. 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 electro-optic devices; optical wave guide applications and designs. Letter grading. Mr. Dunn (W, odd years)

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 as it helps students creatively develop and greatly expand effectiveness of their communication and presentation skills. Letter grading. Mr. Xie (F,W,Sp)

171. Engaging Elements of Communication: Writing for Technical Community. (2) (Formerly numbered 197.) 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 abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and grammar. Letter grading. Mr. Xie (F,W,Sp)

CM180. Introduction to Biomaterials. (4) (Same as Biomedical Engineering CM180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 14, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading. Mr. Wu (Sp)

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 that are taught on experimental or temporary basis, such as courses 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 and current literature in field or of research of faculty members or students. May be repeated for credit. Letter grading.

199. Directed Research in Materials Science and Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating 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

200. Principles of Materials Science I. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Lattice dynamics and thermal properties of solids, classical and quantized free electron theory, electrons in a periodic potential, transport in semiconductors, dielectric and magnetic properties of solids. Letter grading. Mr. Dunn (F)

201. Principles of Materials Science II. (4) Lecture, three hours; outside study, nine hours. Requisite: course 131. Kinetics of diffusional transformations in solids. Precipitation in solids. Nucleation theory. Theory of precipitate growth. Ostwald ripening. Spinodal decomposition. Cellular reactions. Letter grading. Mr. Ardell (Sp)

221. Science of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Study of major physical and chemical principles affecting properties and performance of semiconductor materials. Topics include bonding, carrier statistics, band-gap engineering, optical and transport properties, novel materials systems, and characterization. Letter grading. Mr. Goorsky (Sp)

222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 130, 131. Thermodynamics and kinetics that affect semiconductor growth and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), heteroepitaxy, implantation, oxidation. Letter grading. Mr. Goorsky (W)

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

224. Deposition Technologies and Their Applications. (4) Lecture, three hours; outside study, nine hours. Designed for graduate engineering students. Deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-assisted vapor deposition processes, plasma spray, electrodeposition. Applications in semiconductor, chemical, optical, mechanical, and metallurgical industries. Letter grading. Mr. Xie

225. Materials Science of Surfaces. (4) Lecture, four hours; outside study, eight hours. Requisites: course 120, Chemistry 113A. Introduction to atomic and electronic structure of surfaces. Survey of methods for determining composition and structure of surfaces and near-surface layers of solid-state materials. Emphasis on scanning probe microscopy, Auger electron spectroscopy, X-ray photoelectron spectroscopy, ultraviolet photoelectron spectroscopy, secondary ion mass spectrometry, ion scattering spectroscopy, and Rutherford backscattering spectrometry. Applications in microelectronics, optoelectronics, metallurgy, polymers, biological and biocompatible materials, and catalysis. Letter grading. Mr. Gillis, Mr. Goorsky (W)

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Requisite: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture. Fracture mechanics, dislocation models, fatigue, fracture in reactive environments, alloy development, fracture-safe design. Letter grading. Mr. Ono (W, even years)

243C. Dislocations and Strengthening Mechanisms in Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143A or Mechanical and Aerospace Engineering 156B. Elastic and plastic behavior of crystals, geometry, mechanics, and interaction of dislocations, mechanisms of yielding, work hardening, and other strengthening. Letter grading. Mr. Ardell (F, odd years)

244. Electron Microscopy. (4) Lecture, four hours; outside study, eight hours. Requisite: course 111. Essential features of electron microscopy, geometry of electron diffraction, kinematical and dynamical theories of electron diffraction, including anomalous absorption, applications of theory to defects in crystals. Moiré fringes, direct lattice resolutions, Lorentz microscopy, laboratory applications of contrast theory. Letter grading. Mr. Ardell (Sp, even years)

245C. Diffraction Methods in Science of Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 110. Theory of diffraction of waves (X rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of plastic deformation, solid-state transformations, arrangements of atoms in liquids and amorphous solids. Letter grading.
Mr. Goorsky (Sp, odd years)

246A. Mechanical Properties of Nonmetallic Crystalline Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Material and environmental factors affecting mechanical properties of nonmetallic crystalline solids, including atomic bonding and structure, atomic-scale defects, microstructural features, residual stresses, temperature, stress state, strain rate, size, and surface conditions. Methods for evaluating mechanical properties. Letter grading. Mr. Dunn (W, odd years)

246B. Structure and Properties of Glass. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Structure of amorphous solids and glasses. Conditions of glass formation and theories of glass structure. Mechanical, electrical, and optical properties of glass and relationship to structure. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Principles governing electronic properties of ceramic single crystals and glasses and effects of processing and microstructure on these properties. Electronic conduction, ferroelectricity, and photochromism. Magnetic ceramics. Infrared, visible, and ultraviolet transmission. Unique application of ceramics. Letter grading.
Mr. Dunn (Sp, even years)

250A. Analysis and Design of Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: one course from 143A, Electrical Engineering 175, Mechanical and Aerospace Engineering 156A, or 156B. Requisite: course 151. Mechanics of laminated composites, textile structural composites, strength and failure theory, fracture, fatigue and damage tolerance, environmental effects, microcomputer software for composite analysis and design. Letter grading.
Mr. J-M. Yang (W, even years)

250B. Advanced Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: B.S. in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of advanced composite materials. Fibers; resin-, metal-, and ceramic-matrix composites. Physical, mechanical, and nondestructive characterization techniques. Letter grading.
Mr. Ono (W, odd years)

252. Organic Polymer Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers; heavily doped, highly conducting polymers; applications as processable metals and in various electrical, optical, and electrochemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

CM280. Introduction to Biomaterials. (4) (Same as Biomedical Engineering CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 14, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (Sp)

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

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

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at the University. 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 Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering students. 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.

598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate materials science and 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 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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Oddvar O. Bendiksen, Ph.D.
Gregory P. Carman, Ph.D.
Albert Carnesale, Ph.D., *Chancellor*
Ivan Catton, Ph.D.
Yong Chen, Ph.D.
Vijay K. Dhir, Ph.D., *Dean*
Rajit Gadh, Ph.D.
Nasr M. Ghoniem, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
H. Thomas Hahn, Ph.D. *(Raytheon Company Professor of Manufacturing Engineering)*
Chih-Ming Ho, Ph.D., *Associate Vice Chancellor, Research (Ben Rich Lockheed Martin Professor of Aeronautics)*
Ann R. Karagozian, Ph.D.
Chang-Jin (C-J) Kim, Ph.D.
J. John Kim, Ph.D. *(Rockwell International Professor of Engineering)*
Adrienne G. Lavine, Ph.D.
Kuo-Nan Liou, Ph.D.
Ajit K. Mal, Ph.D.
Anthony F. Mills, Ph.D.
Carlo D. Montemagno, Ph.D.
Jeff S. Shamma, Ph.D.
Owen I. Smith, Ph.D.
Jason Speyer, Ph.D.
Tsu-Chin Tsao, Ph.D.
Daniel C.H. Yang, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti

Andrew F. Charwat, Ph.D.
Peretz P. Friedmann, Sc.D.
Walter C. Hurty, M.S.
Robert E. Kelly, Sc.D.
Cornelius T. Leondes, Ph.D.
Michel A. Melkanoff, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkewitz, Ph.D.
Philip F. O'Brien, M.S.
David Okrent, Ph.D.
Russell R. O'Neill, Ph.D., *Dean Emeritus*
Lucien A. Schmit, Jr., M.S.
Chauncey Starr, Ph.D., *Dean Emeritus*
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.

Associate Professor

Robert T. M'Closkey, Ph.D.

Assistant Professors

Jeff D. Eldredge, Ph.D.

Emilio Frazzoli, Ph.D.
Yongho Sungtaek Ju, Ph.D.
H. Pirouz Kavehpour, Ph.D.
William S. Klug, Ph.D.
Laurent Pilon, Ph.D.

Senior Lecturer

Alexander Samson, Ph.D., *Emeritus*

Lecturers

Ravnesh Amar, Ph.D.
C.H. Chang, M.S., *Emeritus*
Amiya K. Chatterjee, Ph.D.
Wilbur J. Marner, Ph.D.
Rudolf X. Meyer, Dr.Engr., *Emeritus*

Adjunct Professors

Leslie M. Lackman, Ph.D.
Joseph Miller, Ph.D.
Neil B. Morley, Ph.D.
Raymond Viskanta, Ph.D.
Xiang Zhang, Ph.D.

Scope

The Mechanical and Aerospace Engineering Department encompasses professional disciplines that are often divided into separate departments at other engineering schools. Curricula in aerospace engineering and mechanical engineering are offered on both the undergraduate and graduate levels. The Gourman Report ranked UCLA's mechanical engineering program tenth in the nation for undergraduate programs.

Because of the scope of the department, faculty research and teaching cover a wide range of technical disciplines. Research in thermal engineering emphasizes basic heat and mass transfer processes as well as thermal hydraulics. Topics in the area of design, dynamics, and control include robotics, mechanism design, control and guidance of aircraft and spacecraft, aeromechanics, and dynamics and control of large space structures. Studies in structural mechanics range from fracture mechanics and wave propagation, structural dynamics and aeroelasticity of helicopters and jet engine blades, computational transonic aeroelasticity to structural optimization and synthesis, and mechanics of composite structures. In the area of fluid mechanics and acoustics, investigations are under way on combustion, flow instabilities, turbulence and thermal convection, aeroacoustics, and unsteady aerodynamics of turbomachines, helicopter rotors, and fixed-wing aircraft. Other areas of research include applied plasma physics, surface modification by plasma, fusion reactor design, experimental tokamak confinement physics; light water reactor safety; reliability and risk assessment methodology; and nuclear materials. The department also has research activity in computer-aided design and manufacturing.

At the undergraduate level, the department offers accredited programs leading to B.S. degrees in Aerospace Engineering and in Mechanical Engineering. The former includes opportunity to emphasize propulsion, aerodynamics, design, dynamics and control, or structures and space technology, while the latter includes opportunity to emphasize design and manufacturing, dynamics and control, or fluids and thermal engineering.

At the graduate level, the department offers programs leading to M.S. and Ph.D. degrees in Mechanical Engineering and in Aerospace Engineering. An M.S. in Manufacturing Engineering is also offered.

Department Mission

The mission of the Mechanical and Aerospace Engineering Department is to educate the nation's future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological innovation while fostering academic excellence and scholarly learning in a collegial environment.

Undergraduate Program Objectives

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.

Aerospace Engineering B.S.

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.

The Major

Course requirements are as follows (191 minimum units required):

1. Twelve department core courses: Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 20, 101, 102, 103, M105A, 105D, 107, 107L, 157, 182A
2. Eleven aerospace engineering core courses: Mechanical and Aerospace Engineering 150A, 150B, 150P, 154A, 154B, 154S, 157A, 161A or 169A, 166A, 171A, and one mathematics elective from Mechanical and Aerospace Engineering 181A, 182B, 182C, Electrical Engineering 103, 131A
3. Sixteen technical elective units (which should contain enough design units to satisfy the overall program requirement of at least 24 design units) selected from Mechanical and Aerospace Engineering 131A, 131AL, 132A, 133A, 133AL, 150C (heat and mass transfer, thermodynamics, combustion/propulsion); 153A (acoustics); 155, 163A, 169A (unless taken as part of the core), 171B, Civil and Environmental Engineering 137L, Electrical Engineering 142 (dynamics and control); Mechanical and Aerospace Engineering 166C, 168, 183 (structural and solid mechanics); Mechanical and Aerospace Engineering 150R, 161A (unless taken as part of the core), 161B, 161C, 161D (space technology); 162A, 162C (design and mechanisms); Materials Science and Engineering 143A
4. Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details

Mechanical Engineering B.S.

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

The Major

Course requirements are as follows (193 minimum units required):

1. Twelve department core courses: Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 20, 101, 102, 103, M105A, 105D, 107, 107L, 157, 182A
2. Ten mechanical engineering core courses: Electrical Engineering 110L, Mechanical and Aerospace Engineering 94, 131A, 133A, 156A, 162A, 162B, 162M, 171A, 183
3. Twenty technical elective units, to be selected from the three subject areas listed below, of which at least 12 units (including at least 4 laboratory units) should be from a single subject area:
   a. *Design and Manufacturing:* Materials Science and Engineering 143A, Mathematics 120A, Mechanical and Aerospace Engineering CM140, 155, 163A, 166C, 168, 171B, 174, M180; laboratory courses: Mechanical and Aerospace Engineering 162C, 172, M180L, 184, 185
   b. *Dynamics and Control:* Electrical Engineering 102, 103, 131A, 131B, Materials Science and Engineering 143A, Mathematics 115A, 115B, 131A, 131B, Mechanical and Aerospace Engineering CM140, 155, 163A, 168, 171B, 174, 181A; laboratory courses: Civil and Environmental Engineering 137L, Mechanical and Aerospace Engineering 162C, 172
   c. *Fluids and Thermal Engineering:* Electrical Engineering 103, Mechanical and Aerospace Engineering 132A, 134, 150A, 150B, 150C, 150P, 150R, 153A, 161A, 161B, 174, 182B, 182C; laboratory courses: Mechanical and Aerospace Engineering 131AL, 133AL, 157A
4. Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see School Requirements on page 21 and http://www.registrar.ucla.edu/ge/GE-ENGRNew05-06.pdf for details
6. Four free technical elective units selected from upper division courses offered by the department; students are strongly encouraged to consult their adviser

Lead by Cathy Leong, the Student Design/Build/Fly Competition team included Saul Rios, Alan Hui, Kevin Archibald, Jerry Huang, and Gerard Toribio.

Graduate Study

For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2005-06 edition of *Program Requirements for UCLA Graduate Degrees*. Complete annual editions of *Program Requirements* are available from the “Publications” link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in *Program Requirements* for the year in which they matriculate.

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.

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. 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 M105A, 199; Civil and Environmental Engineering 106A, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 105D, 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 or 156B, (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, 255A, M256A, M256B, M269A, or 271A. 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, (3) take and pass three extra examination questions offered separately from each of the finals of three graduate courses, to be selected by the committee from a set of common department courses, or (4) take and pass an oral examination administered by the M.S. committee. In case of failure, students may be reexamined once with the consent of the graduate adviser.

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. 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 M105A, 199; Civil and Environmental Engineering 106A, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, 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, M105A, 105D, 199.

Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 163A, 168, 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, M280, 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, 243A, 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, (3) take and pass three extra examination questions offered separately from each of the finals of three graduate courses, to be selected by the committee from a set of common department courses, or (4) take and pass an oral examination administered by the M.S. committee. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students would normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Aerospace Engineering Ph.D. and Mechanical Engineering Ph.D.

Major Fields or Subdisciplines

Dynamics; fluid mechanics; heat and mass transfer; manufacturing and design (mechanical engineering only); nanoelectromechanical/microelectromechanical systems (NEMS/MEMS); structural and solid mechanics; systems and control.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature and (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 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 quarter following the quarter in which the examination is given. The examination must be taken within the first two calendar years from the time of admission to the Ph.D. program. Students must be registered during the quarter in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student's major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field.

After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years from the time of admission to 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 at UCLA in the student's major department in HSSEAS. The "outside" member must be a UCLA faculty member outside the student's major 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; aeromechanical stability of helicopters; active control of helicopter vibrations; experimental studies of electromechanical systems; and robotics.

Fluid Mechanics

The fluid mechanics field includes theoretical, numerical, and experimental studies related to topics in fluid mechanics such as fluid instabilities, flow transition, numerical simulation of turbulence, flow control, computational aerodynamics, hypersonic flow, aerodynamic noise production, high-speed combustion, acoustically driven combusting flows, laser diagnostics, microgravity studies of interfacial phenomena and combustion, thermocapillary convection, and microscale/nanoscale fluid mechanics and combustion.

Heat and Mass Transfer

The heat and mass transfer field includes studies of convection, radiation, conduction, evaporation, condensation, boiling, two-phase flow, instability and turbulent flow, microscale and nanoscale heat transfer and direct energy conversion, and reactive flows in porous media.

Manufacturing and Design

The manufacturing and design field is developed around an integrated approach to manufacturing and mechanical product design. It includes research on material behavior (physical and mechanical) in manufacturing processes and in design; design of mechanical systems (e.g., power, microelectromechanical systems, and transportation); design methodology; automation, robotics, and unmanned machinery; manufacturing and mechanical systems (reliability, safety, and optimization); CAD/CAM theory and applications; computational geometry and geometrical modeling.

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 nano/micro fabrication 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 field 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, and investigation into coupled electro-magneto-thermomechanical material systems. The structural mechanics field includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aeroelasticity, fluid structure interaction, computational transonic aeroelasticity, structural optimization, finite element methods and related computational techniques, mechanics of composite structures, and analysis of adaptive structures.

Systems and Control

The systems and control field deals with modeling, analysis, and control of dynamical systems. Applied mathematics is used to develop methods for stability analysis, design of optimal and robust control systems, filtering, and system identification. Courses and research programs include theoretical analysis of the performance of systems and algorithms; computational methods for simulation, optimization, control, filtering, and identification; and experimental studies involving system identification and hardware implementation of real-time control and filtering. The field covers a broad spectrum of applications areas, primarily emphasizing problems in mechanical and aerospace engineering.

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.

1. The *Micro-Manufacturing Laboratory* is equipped with a fume hood, a clean air bench, an optical table, a DI water generator, dicing saw, plating setup with Dynatronix power supply, Wentworth probe stations, various microscopes such as Endo View and Hirox 3-D High-Scope System, full video imaging capability such as a Sony Digital Camera system, as well as L-Edit mask layout software. It is used for MEMS 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.
2. 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.
3. The *Autonomous Vehicle Systems Instrumentation Laboratory* (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. The AVSIL contains a hardware-in-the-loop (HIL) simulator designed and built at UCLA that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the Interstate Electronics Corporation GPS Satellite Constellation Simulator. The UCLA flight control software can be modified to accommodate satellite-system experiments using real-time software, GPS receivers, and inter-vehicle modem communication.
4. The *Nanoscale Heat Transfer and Thermoelectrics Laboratory* (Nano-HTTL) is equipped with a scanning probe microscope (atomic force, scanning tunneling, scanning thermal, and scanning laser), infrared microscope with 4πm resolution, gas and solid-state lasers (argon, T-Sapphire, and semiconductor lasers) and optical systems, vacuum systems for low- to high-temperature property measurement (4 K-800 K), a probe station, various thin-film thermal conductivity and Seebeck coefficient measurement systems, analytical equipment, various computers for data acquisition, and an HP workstation for computational work.
5. 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.
6. The 3 x 3-foot *Subsonic Wind Tunnel* is used for research on unsteady aerodynamics on oscillating airfoils and instruction.
7. 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.
8. 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.
9. The *Computational Fluid Dynamics Laboratory* has several medium-size Beowolf linux clusters for numerical simulation of transitional, turbulent, and high speed compressible flows, with and without reaction, as well as the sound that they produce. The labora-

tory has access to supercomputers (large clusters of parallel processors on various platforms) at NSF PACI Centers and DoD High-Performance Computing Centers.

10. The *Combustion Research Laboratory* includes a resonant dump combustor for the study of hazardous waste incineration, mixing and combustion tunnels for study of emissions reduction in fuel injection systems, and several flat flame burners and flow reactors. There are also extensive optical diagnostic capabilities. For flight testing, facilities at NASA Dryden Flight Research Center are used.
11. The *Fusion 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, (2) thick and thin liquid metal systems exposed to intense particle and heat flux loads, and (3) metallic and ceramic material thermomechanics.
12. 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.
13. The *Microsciences Laboratory* is equipped with advanced sensors and imaging processors for exploring fundamental physical mechanisms in MEMS-based sciences.
14. 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.
15. 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.

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; neutronics, plasma-material interactions; blankets and high heat flux components; experiments, modeling and analysis

Oddvar O. Bendiksen, Ph.D. (UCLA, 1980)
Classical and computational aeroelasticity, structural dynamics and unsteady aerodynamics

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models, fatigue characterization of piezoelectric ceramics, magnetostrictive composites, characterizing shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally evaluating damage in composites

Albert Carnesale, Ph.D. (North Carolina State, 1966)
Issues associated with nuclear weapons and other weapons of mass destruction, energy policy, American foreign policy

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

Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, micro- and nano-scale 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, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

James S. Gibson, Ph.D. (U. Texas, Austin, 1975)
Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

H. Thomas Hahn, Ph.D. (Pennsylvania State, 1971)
Nanocomposites, multifunctional composites, nanomechanics, rapid prototyping, information systems

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, nanoelectro-mechanical/microelectromechanical systems, direct handling of macromolecules, bionano technologies, DNA-based micro sensors

Ann R. Karagozian, Ph.D. (Cal Tech, 1982)
Fluid mechanics of combustion systems with emphasis on acoustically controlled reacting flows detonation phenomena, high-speed combustion systems, and microgravity combustion

Chang-Jin (C-J) Kim, Ph.D. (UC Berkeley, 1991)
Microelectromechanical systems, micromachining technologies, microstructures, sensors and actuators, microdevices and systems, micromanufacturing, microscale mechanics

J. John Kim, Ph.D. (Stanford, 1978)
Turbulence, numerical simulation of turbulent and transitional flows, application of control theories to flow control

Adrienne G. 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 and satellite remote sensing with application to clouds and aerosols in the earth's atmosphere

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

Anthony F. Mills, Ph.D. (UC Berkeley, 1965)
Convective heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers

Carlo D. Montemagno, Ph.D. (Notre Dame, 1995)
Nanoscale biomedical systems, microrobotics, directed self-assembly, hybrid living/nonliving device engineering, pathogen detection and tissue engineering

Jeff S. Shamma, Ph.D. (MIT, 1988)
Feedback control theory and design with application to mechanical, aerospace, and manufacturing systems

Owen I. Smith, Ph.D. (UC Berkeley, 1977)
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor 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 systems, 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 systems, computer-controlled machines

Xiaolin Zhong, Ph.D. (Stanford, 1991)
Computational fluid dynamics, hypersonic flow, rarefied gas dynamics, numerical simulation of transient hypersonic flow with nonequilibrium 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

Peretz P. Friedmann, Sc.D. (MIT, 1972)
Aeroelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aeroelastic constraints

Walter C. Hurty, M.S. (UCLA, 1948)
Dynamics of structures, including large structural systems, design and analysis of aerospace structures, stability of motion in self-excited systems

Robert E. Kelly, Sc.D. (MIT, 1964)
Thermal convection, thermocapillary convection, stability of shear flows, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics

Cornelius T. Leondes, Ph.D. (Pennsylvania, 1954)
Applied dynamic systems control

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

D. Lewis Mingori, Ph.D. (Stanford, 1966)
Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles

Peter A. Monkewitz, Ph.D. (E.T.H., Federal Institute of Technology, Zurich, 1977)
Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip F. O'Brien, M.S. (UCLA, 1949)
Industrial engineering, environmental design, thermal and luminous engineering systems

David Okrent, Ph.D. (Harvard, 1951)
Fast reactors, reactor physics, nuclear reactor safety, nuclear fuel element behavior, risk-benefit studies, nuclear environmental safety, fusion reactor technology

Russell R. O'Neill, Ph.D. (UCLA, 1956)
Systems engineering, maritime transportation systems

Lucien A. Schmit, Jr., M.S. (MIT, 1950)
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components

Chauncey Starr, Ph.D. (Rensselaer, 1935)
Risk-benefit analysis of technical systems, national energy policy

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 mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems

Associate Professor

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

Assistant Professors

Jeff D. Eldredge, Ph.D. (Cal Tech, 2002)
Aeroacoustics, particle-based numerical methods for fluids, control of acoustically-driven instabilities, vorticity dynamics

Emilio Frazzoli, Ph.D. (MIT, 2001)
Algorithmic, geometric, and computational methods for control of autonomous and distributed aerospace systems; flight control, astrodynamics, robotics, hybrid systems

Yongho Sungtaek Ju, Ph.D. (Stanford, 1999)
Heat transfer, thermodynamics, micro- and nano-electromechanical systems (MEMS/NEMS), magnetism, nano-bio technology

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

William S. Klug, Ph.D. (Cal Tech, 2003)
Computational structural and solid mechanics, finite element methods, computational biomechanics, nanomechanics of biological systems

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

Senior Lecturer

Alexander Samson, Ph.D. (U. New South Wales, 1968), *Emeritus*
Electromechanical system design, mechanical design, design of mechanical energy systems

Lecturers

Ravnesh Amar, Ph.D. (UCLA, 1974)
Heat transfer and thermal science

C.H. Chang, M.S. (UCLA, 1985), *Emeritus*
Computer-aided manufacturing and numerical control

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

Wilbur J. Marner, Ph.D. (South Carolina, 1969)
Thermal sciences, system design

Rudolf X. Meyer, Dr.Engr. (Johns Hopkins, 1955), *Emeritus*
Space technology

Adjunct Professors

Leslie M. Lackman, Ph.D. (UC Berkeley, 1967)
Structural analysis and design, composite structures

Joseph Miller, Ph.D. (UCLA, 1962)
High-energy lasers, space instruments, space propulsion, multidisciplinary project management and leadership, engineering and society

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

Raymond Viskanta, Ph.D. (Purdue, 1960)
Radiative transfer, heat transfer in combustion systems, heat transfer in manufacturing, simulation of electronic devices using Boltzmann Transport Equation

Xiang Zhang, Ph.D. (UC Berkeley, 1996)
Nano-micro fabrication and MEMS, laser microtechnology, nano-micro devices (electronic, mechanical, photonic, and biomedical), rapid prototyping and microstereo lithography, design and manufacturing in nano-microscale, semiconductor manufacturing, physics and chemistry in nano-micro devices and fabrication.

Lower Division Courses

10. Introduction to Mechanical and Aerospace Engineering. (2) Lecture, two hours. Overview of fluid mechanics, heat and mass transfer, manufacturing and design, microelectromechanical systems, structural and solid mechanics, systems, dynamics and control. Careers in mechanical and aerospace engineering industry. P/NP grading. Mr. Hahn (W)

15. Technical Communication for Engineers. (2) Lecture, two hours; outside study, four hours. Requisite: English Composition 3. Understanding writing process. Determining the purpose. Prewriting. Principles of organizing technical information. Eliminating unnecessary words, structuring paragraphs clearly, structuring effective sentences. Writing abstracts, introductions, and conclusions. Drafting and revising coherent documents. Writing collaboratively. Letter grading. Ms. Lavine (W,Sp)

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

20. Programming with Numerical Methods Applications. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Mathematics 31A, 31B. Introduction to programming with MATLAB. Applications to numerical methods used in engineering. Letter grading. Ms. Lavine (F,W,Sp)

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 on-line 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 enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

101. Statics and Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 31A, 31B, Physics 1A. Review of vector representation of forces, resultant force and moment, equilibrium of concurrent and nonconcurrent forces. Determinate and indeterminate force systems. Area moments and products of inertia. Support reactions and free-body diagrams for simple models of mechanical and aerospace structures. Internal forces in beams, shear and moment diagrams. Cauchy's stress and linear strain components in solids, equilibrium equations, Hooke's law for isotropic solids. Saint Venant's problems of extension, bending, flexure, and torsion. Deflection of symmetric beams. Axial and hoop stresses in thin-walled pressure vessels. Letter grading. Mr. Mal (F,W)

102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisites: course 101, Mathematics 33A, Physics 1A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in two and three dimensions. Impulse-momentum and work-energy relationships. Applications. Letter grading. Mr. Klug (F,W,Sp)

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.
Mr. Kavehpour, Mr. J. Kim (F,W,Sp)

M105A. Introduction to Engineering Thermodynamics. (4) (Same as Chemical Engineering M105A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Concepts of equilibrium, temperature, and reversibility. First law and concept of energy; second law and concept of entropy. Equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading. Mr. Pilon (F,W,Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103, M105A, Mathematics 32B, 33B. Transport phenomena; heat conduction, mass species diffusion, convective heat and mass transfer, and radiation. Engineering applications in thermal and environmental control. Letter grading. Mr. Ju (F,W,Sp)

107. Introduction to Modeling and Analysis of Dynamic Systems. (3) Lecture, three hours; discussion, one hour; outside study, four hours. Requisites: courses 20, 102. Corequisite: course 107L. Introduction to modeling of physical systems, including mechanical, fluid, thermal, and electrical systems. Linear differential equations. Description of these systems with coverage of superposition, 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, and numerical solution. Block diagram representation and response of interconnections of systems. Letter grading.
Mr. M'Closkey, Mr. Tsao (F,W,Sp)

107L. Dynamic Systems Laboratory. (1) Laboratory, two hours; outside study, two hours. Requisites: courses 20, 102. Investigation of dynamic behavior of physical systems by computer simulation and hands-on experiments. Computer-based data acquisition. Time and frequency domain modeling and analysis of mechanical, electrical, thermal, and fluid lumped parameter systems. Letter grading.
Mr. M'Closkey, Mr. Tsao (F,W,Sp)

131A. Intermediate Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 20, 105D, 182A. Steady conduction: two-sided, two-ended, tapered, and circular fins; buried cylinders, thick fins. Transient conduction: slabs, cylinders, products. Convection: transpiration, laminar pipe flow, film condensation, boundary layers, dimensional analysis, working correlation, surface radiation. Two-stream heat exchangers. Elements of thermal design. Letter grading. Ms. Lavine (F,W)

131AL. Thermodynamics and Heat Transfer Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 131A, 157. Experimental study of physical phenomena and engineering systems using modern data acquisition and processing techniques. Experiments include studies of heat transfer phenomena and testing of a cooling tower, heat exchanger, and internal combustion engine. Students take and analyze data and discuss physical phenomena. Letter grading.
Mr. Mills (Sp, alternate years)

132A. Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Principles of mass transfer by diffusion and convection. Simultaneous heat and mass transfer. Analysis of evaporative and transpiration cooling, combustion, and catalysis. Mass exchangers, including automobile catalytic converters, precipitators, filters, scrubbers, humidifiers, and cooling towers. Letter grading.
Mr. Mills (F, alternate years)

133A. Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, M105A, 105D. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, reactive and nonreactive fluid flow systems. Letter grading. Mr. Catton (F,Sp)

133AL. Power Conversion Thermodynamics Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 133A, 157. Experimental study of power conversion and heat transfer systems using state-of-the-art plant process instrumentation and equipment. Experiments include studies of thermodynamic operating characteristics of an actual Brayton cycle, Rankine cycle, compressive refrigeration unit, and absorption refrigeration unit. Letter grading. Mr. Catton (W, alternate years)

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 (Sp)

CM140. Introduction to Biomechanics. (4) (Same as Biomedical Engineering CM140.) Lecture, four hours; outside study, eight hours. Requisites: courses 102 (or Civil Engineering 108), 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 generation. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading.
Mr. Gupta, Mr. Kabo (W)

150A. Intermediate Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 20, 103, 182A. Basic equations governing fluid motion. Fundamental solutions of Navier/Stokes equations. Lubrication theory. Elementary potential flow theory. Boundary layers. Turbulent flow in pipes and boundary layers. Compressible flow: normal shocks, channel flow with friction or heat addition. Letter grading.
Mr. Eldredge, Ms. Karagozian (W)

150B. Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 150A. Advanced aspects of potential flow theory. Incompressible flow around thin airfoils (C_l, C_m) and wings (lift, induced drag). Gas dynamics: oblique shocks, Prandtl/Meyer expansion. Linearized subsonic and supersonic flow around thin 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, M105A, 105D. Chemical thermodynamics of ideal gas mixtures, premixed and diffusion flames, explosions and detonations, combustion chemistry, high explosives. Combustion processes in rocket, turbine, and internal combustion engines; heating applications. Letter grading.
Ms. Karagozian, Mr. Smith (W)

150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, M105A. Thermodynamic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Letter grading. Ms. Karagozian, Mr. Smith (F)

150R. Rocket Propulsion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, M105A, 105D. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Letter grading. Ms. Karagozian, Mr. Smith (Sp)

153A. Engineering Acoustics. (4) Lecture, four hours; outside study, eight hours. Designed for junior/senior engineering majors. Fundamental course in acoustics; propagation of sound; sources of sound. Design of field measurements. Estimation of jet and blade noise with design aspects. Letter grading.
Mr. Eldredge (Sp, alternate years)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; outside study, eight hours. Requisite: course 154S. Classical preliminary design of an aircraft, including weight estimation, performance and stability, and control consideration. Term assignment consists of preliminary design of a low-speed aircraft. Letter grading. Mr. Bendiksen (W)

154B. Design of Aerospace Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 154A, 166A. Design of aircraft, helicopter, spacecraft, and related structures. External loads, internal stresses. Applied theory of thin-walled structures. Material selection, design using composite materials. Design for fatigue prevention and structural optimization. Field trips to aerospace companies. Letter grading. Mr. Bendiksen (Sp)

154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed for design of an aircraft. Effects of airplane flexibility on stability derivatives. Letter grading. Mr. Bendiksen (F)

155. Intermediate Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrange equation, variational principles; central force motion; kinematics and dynamics of a rigid body. Euler equations, motion of rotating bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading. Mr. Gibson (F)

156A. Strength of Materials. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisites: courses 101, 182A. 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. Mal (F,Sp)

157. Basic Mechanical Engineering Laboratory. (4) Laboratory, four hours; outside study, eight hours. Requisites: courses 101, 103, M105A, 105D, Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Ghoniem, Mr. Mills (F,W,Sp)

157A. Fluid Mechanics and Aerodynamics Laboratory. (4) Laboratory, eight hours. Requisites: courses 150A, 150B, 157. 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 the field. Letter grading. Mr. Kavehpour, Mr. Smith (Sp)

161A. Introduction to Astronautics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102. Recommended: course 182A. Space environment of Earth, trajectories and orbits, step rockets and staging, two-body problem, orbital transfer and rendezvous, problem of three bodies, elementary perturbation theory, influence of Earth's oblateness. Letter grading. Mr. Hahn (F)

161B. Introduction to Space Technology. (4) Lecture, four hours; outside study, eight hours. Recommended preparation: courses 102, 105D, 150P, 161A. Propulsion requirements for typical space missions, thermochemistry of propellants, internal ballistics, regenerative cooling, liquid propellant feed systems, POGO instability. Electric propulsion. Multistage rockets, separation dynamics. Satellite structures and materials, loads and vibrations. Thermal control of spacecraft. Letter grading. Mr. Hahn (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 161B. Coverage of preliminary design, by students, of a small spacecraft carrying a lightweight scientific payload with modest requirements for electric power, lifetime, and attitude stability. Students work in groups of three or four, with each student responsible primarily for a subsystem and for integration with the whole. Letter grading. Mr. Bendiksen (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 the students. New project carried out each year. Letter grading. Mr. Frazzoli (W)

162A. Introduction to Mechanisms and Mechanical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 20, 102. Analysis and synthesis of mechanisms and mechanical systems. Kinematics, dynamics, and mechanical advantages of machinery. Displacement velocity and acceleration analyses of linkages. Fundamental law of gearing and various gear trains. Computer-aided mechanism design and analysis. Letter grading. Mr. Yang (F,Sp)

162B. Mechanical Product Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 94, 156A, 162A, 193, Electrical Engineering 110L. Lecture and laboratory (design) course involving modern design theory and methodology for development of mechanical products. Economics, marketing, manufacturability, quality, and patentability. Design considerations taught and applied to hands-on design project. Letter grading. Mr. Ghoniem (F,W)

162C. Electromechanical System Design Laboratory. (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 (Sp)

162M. Senior Mechanical Engineering Design. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 131A, 133A, 162B, 169A, 171A. Must be taken in last two academic terms of students' programs. Analytical course of a large engineering system. Design factors include functionality, efficiency, economy, safety, reliability, aesthetics, and social impact. Final report of engineering specifications and drawings to be presented by design teams. Letter grading. Mr. Yang (W,Sp)

163A. Introduction to Computer-Controlled Machines. (4) Lecture, four hours; outside study, eight hours. Requisite or corequisite: course 171A. Modeling of computer-controlled machines, including electrical and electronic elements, mechanical elements, actuators, sensors, and overall electromechanical systems. Motion and command generation, servo-controller design, and computer/machine interfacing. Letter grading. Mr. Tsao (F)

166A. Analysis of Flight Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101. 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 used in aerospace vehicles; elements of plate theory; buckling of columns. Letter grading. Mr. Klug (F)

166C. Design of Composite Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, failure analysis, design examples and design studies, buckling of composite components, nonsymmetric laminates, micromechanics of composites. Letter grading. Mr. Carman (W)

168. Introduction to Finite Element Technology. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: courses 20, 101, Mathematics 33A. Recommended: courses 94 or 184, 166A. Introduction to finite element method (FEM) and its matrix formulation of computer implementation of FEM concepts; practical use of FEM codes. Preprocessing and postprocessing techniques; graphics display capabilities; geometric and analysis modeling; interactive engineering systems; links with computer-aided design. Recent trends in FEM technology; design optimization. Term projects using FEM computer codes. Letter grading. Mr. Klug (Sp)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102, 182A, Civil Engineering 108. Recommended: Electrical Engineering 102. 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,W)

171A. Introduction to Feedback and Control Systems: Dynamic Systems Control I. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181A or 182A or Electrical Engineering 102. Introduction to feedback principles, control systems design, and system stability. Modeling of physical systems 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. Shamma (F,W,Sp)

171B. Digital Control of Physical Systems. (4) (Formerly numbered 164.) Lecture, four hours; outside study, eight 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 locus, frequency response, loop-shaping compensation. Design using state-space methods: state feedback, state estimator, state estimator feedback control. Simulation of sampled data systems and practical aspects: roundoff errors, sampling rate selection, computation delay. Letter grading. Mr. Tsao (Sp)

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 controller design requires students to formulate performance measures for control problem, experimentally identify mechanical systems, and develop uncertainty descriptions for design models. Exploration of issues concerning model uncertainty and sensor/actuator placement. Students implement control designs on flexible structures, rate gyroscope, and inverted pendulum. Detailed reports required. Letter grading. Mr. M'Closkey (W)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; outside study, eight hours. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading. Mr. Hahn (W)

M180. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Biomedical Engineering M150 and Electrical Engineering M150.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course M180L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Letter grading. Mr. C-J. Kim (F)

M180L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Formerly numbered 180.) (Same as Biomedical Engineering M150L and Electrical Engineering M150L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Corequisite: course M180. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Letter grading. Mr. C-J. Kim (F)

181A. Complex Analysis and Integral Transforms. (4) (Formerly numbered 191A.) Lecture, four hours; outside study, eight hours. Requisite: course 182A. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transform: properties, convolution, inversion; Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. Ghoniem (W)

182A. Mathematics of Engineering. (4) (Formerly numbered 192A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A, 33B. Methods of solving ordinary differential equations in engineering. Review of matrix algebra. Solutions of systems of first- and second-order ordinary differential equations. Introduction to Laplace transforms and their application to ordinary differential equations. Introduction to boundary value problems. Letter grading. Mr. Mal (F,W,Sp)

182B. Mathematics of Engineering. (4) (Formerly numbered 192B.) Lecture, four hours; outside study, eight hours. Requisite: course 182A. Analytical methods for solving partial differential equations arising in engineering. Separation of variables, eigenvalue problems, Sturm/Liouville theory. Development and use of special functions. Representation by means of orthonormal functions; Galerkin method. Use of Green's function and transform methods. Letter grading. Mr. Eldredge, Mr. J. Kim (Sp)

182C. Numerical Methods for Engineering Applications. (4) (Formerly numbered 192C.) Lecture, four hours; outside study, eight hours. Requisites: courses 20, 182A. Recommended: Electrical Engineering 103. Basic topics from numerical analysis having wide application in solution of practical engineering problems, computer arithmetic, and errors. Solution of linear and nonlinear systems. Algebraic eigenvalue problem. Least-square methods, numerical quadrature, and finite difference approximations. Numerical solution of initial and boundary value problems for ordinary and partial differential equations. Letter grading. Mr. Zhong (F)

183. Introduction to Manufacturing Processes. (4) (Formerly numbered 193.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Materials Science 14. Manufacturing fundamentals. Materials in manufacturing. Manufacturing systems. Rapid prototyping. Material removal processes. Solidification and forming. Joining and assembly. Particulate and surface processes. Electronics manufacturing. Letter grading.
Mr. Hahn, Mr. C-J. Kim (F,Sp)

184. Introduction to Geometry Modeling. (4) (Formerly numbered 194.) Laboratory, eight hours; outside study, four hours. Requisites: courses 20, 94. Fundamentals in parametric curve and surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transformations, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and implementation. Letter grading. Mr. Yang (W)

185. Computer Numerical Control and Applications. (4) (Formerly numbered 195.) Laboratory, eight hours; outside study, four hours. Designed for juniors/seniors. Fundamentals of numerical control (NC) technology. Programming of computer numerical control (CNC) machines in NC codes and APT language and with CAD/CAM systems. NC postprocessors and distributed numerical control. Operation of CNC lathe and milling machines. Programming and machining of complex engineering parts. Letter grading. Mr. Yang (Sp)

C187L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (2 to 4) Lecture, two hours; laboratory, two 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, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C287L. Letter grading.
Mr. Chen (Sp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) (Formerly numbered 198.) Lecture, two to four hours; outside study, four to eight hours. Special topics in mechanical and aerospace engineering for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. 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 for credit. P/NP or letter grading.

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

Graduate Courses

231A. Convective Heat Transfer Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 182B. Recommended: course 250A. Conservation equations for flow of real fluids. Analysis of heat transfer in laminar and turbulent, incompressible and compressible flows. Internal and external flows; free convection. Variable wall temperature; effects of variable fluid properties. Analogies among convective transfer processes. Letter grading.
Ms. Lavine (W)

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: 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)

231C. Boiling and Condensation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Phenomenological theories of boiling. Hydrodynamic instability of liquid-vapor interfaces and their application to predict maximum and minimum heat fluxes. Forced flow boiling and boiling crisis in pipes. Pool and forced flow boiling of liquid metals. Film and dropwise condensation. Letter grading.
Mr. Mills (W)

231D. Application of Numerical Methods to Transport Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisite: course 132A. Numerical techniques for solving selected problems in heat and mass transfer. Applications include free convection, boundary layer flow, two-phase flow, separated flow, flow in porous media. Effects of concentration and temperature gradients, chemical reactions, radiation, electric and magnetic fields. Letter grading.
Mr. Catton (Sp)

231E. Two-Phase Flow Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Generalized constitutive equations for various two-phase flow regimes. Interfacial heat and mass transfer. Equilibrium and nonequilibrium flow models. Two-phase flow instability. One-dimensional wave propagation. Two-phase heat transfer applications: convective boiling, pressure drop, critical and oscillatory flows. Letter grading.
Mr. Catton (Sp, alternate years)

231F. Advanced Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 231A. Advanced topics in heat transfer from current literature. Linear and nonlinear theories of thermal and hydrodynamic instability; variational methods in transport phenomena; phenomenological theories of turbulent heat and mass transport. Letter grading.
Mr. Catton (Sp, alternate years)

231G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electronics, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equations, derivation of classical laws from Boltzmann transport equations, deviation from classical laws at small scale. Letter grading. Mr. Ju (Sp)

232B. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 132A. Formulation of general convective heat and mass transfer problem, including equilibrium and nonequilibrium chemistry. Similar and nonsimilar solutions for laminar flows; solution procedures for turbulent flows. Multicomponent diffusion. Application to hypersonic boundary layer, ablation and transpiration cooling, combustion. Letter grading. Mr. Mills (Sp)

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 135, 192A. 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

M237B. Fusion Plasma Physics and Analysis. (4) (Same as Electrical Engineering M287.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering M185. Fundamentals of plasmas at thermonuclear burning conditions. Fokker/Planck equation and applications to heating by neutral beams, RF, and fusion reaction products. Bremsstrahlung, synchrotron, and atomic radiation processes. Plasma surface interactions. Fluid description of burning plasma. Dynamics, stability, and control. Applications in tokamaks, tandem mirrors, and alternate concepts. Letter grading.
Mr. Abdou (W)

237D. Fusion Engineering and Design. (4) Lecture, four hours; outside study, eight hours. Fusion reactions and fuel cycles. Principles of inertial and magnetic fusion. Plasma requirements for controlled fusion. Plasma-surface interactions. Fusion reactor concepts and technological components. Analysis and design of high heat flux components, energy conversion and tritium breeding components, radiation shielding, magnets, and heating. Letter grading.
Mr. Abdou (Sp, alternate years)

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. May be repeated for credit. S/U grading.

239D. Seminar: Current Topics in Nuclear 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, student presentations, and projects in areas of current interest in nuclear engineering. May be repeated for credit. S/U grading.

239F. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measurement techniques. May be repeated for credit with topic change. S/U grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear 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 treatment of subjects selected from research areas 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, eight hours. Requisites: courses 102 (or Civil Engineering 108), 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 generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.
Mr. Gupta, Mr. Kabo (W)

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.
Mr. Eldredge, Mr. J. Kim (F)

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. States of fluid motion discussed in order of advancing Reynolds number; wakes, boundary layers, instability, transition, and turbulent shear flows. Letter grading.
Ms. Karagozian, Mr. J. Kim (W)

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Effects of compressibility in viscous and inviscid flows. Steady and unsteady inviscid subsonic and supersonic flows; method of characteristics; small disturbance theories (linearized and hypersonic); shock dynamics. Letter grading.
Ms. Karagozian, Mr. Zhong (Sp)

250D. Computational Aerodynamics. (4) Lecture, eight hours. Requisites: courses 150A, 150B, 182C. Introduction to useful methods for computation of aerodynamic flow fields. Coverage of potential, Euler, and Navier/Stokes equations for subsonic to hypersonic speeds. Letter grading.
Mr. Zhong (W, alternate years)

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. Particular emphasis on techniques of solving unsteady three-dimensional Navier/Stokes equations. Topics include spectral representation of functions, discrete Fourier transform, etc. Letter grading. Mr. J. Kim (Sp, alternate years)

250F. Hypersonic and High-Temperature Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 250C. Molecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermodynamics for calculation gas properties, equilibrium flows of real gases, vibrational and chemical rate processes, nonequilibrium flows of real gases, and computational fluid dynamics methods for nonequilibrium hypersonic flows. Letter grading. Mr. Zhong (W)

252A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Mechanisms by which laminar flows can become unstable and lead to turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; boundary layer instability. Nonlinear aspects: sufficient criteria for stability, subcritical instabilities, supercritical states, transition to turbulence. Letter grading. Mr. Zhong (W, odd years)

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, turbulence modeling, numerical simulations of turbulent flows, and turbulence control. Letter grading.
Mr. J. Kim (Sp)

252C. Fluid Mechanics of Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Recommended: course 250C. Review of fluid mechanics and chemical thermodynamics applied to reactive systems, laminar diffusion flames, premixed laminar flames, stability, ignition, turbulent combustion, supersonic combustion. Letter grading.
Ms. Karagozian (F, odd years)

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, statistical reaction rate theories. Practical examples of large-scale chain mechanisms from combustion chemistry of several elements, etc. Letter grading.
Mr. Smith (Sp, even years)

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

253B. Fundamentals of Aeroacoustics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Detailed discussion of plane waves, point sources. Nonlinearity, layered and moving media, multiple reflections. Inhomogeneous wave equation. Monopole, dipole, quadrupole source fields from scattering inhomogeneities and turbulence; Lighthill theory; moving sources. Similarity methods. Selected detailed applications. Letter grading. Mr. Eldredge

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

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; procession and nutation of spinning bodies. Letter grading.
Mr. Frazzoli (W)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Concepts of stability; state-space interpretation; stability determination by simulation, linearization, and Liapunov direct method; the Hamiltonian as a Liapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and nonlinear resonance. Application to mechanical systems. Letter grading. Mr. M'Closkey (Sp, odd years)

M256A. Linear Elasticity. (4) (Formerly numbered 256A.) (Same as Civil Engineering M230A.) 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 equation method. Letter grading. Mr. Mal (F)

M256B. Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Solution of linear elastostatic problems using special techniques. Field equations of linear elastostatics; uniqueness of solution; Betti/Rayleigh reciprocity relation; solution of two-dimensional problems using stress functions; stress concentration at holes and inclusions; complex variables and transform methods in elasticity; stress singularity at cracks and corners; stresses and strains in composites; three-dimensional problems — Kelvin, Boussinesq, and Cerruti problems, boundary integral equation method. Letter grading.
Mr. Dong, Mr. Mal (W)

M256C. Plasticity. (4) (Same as Civil Engineering M239.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Classical rate-independent plasticity theory, yield functions, flow rules and thermodynamics. Classical rate-dependent viscoplasticity, Perzyna and Duvant/Lions types of viscoplasticity. Thermoplasticity and creep. Return mapping algorithms for plasticity and viscoplasticity. Finite element implementations. Letter grading. Mr. Gupta (Sp)

256F. Analytical Fracture Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 156A, 156B, or 166A, and Materials Science 243A. Review of modern fracture mechanics, elementary stress analyses; analytical and numerical methods for calculation of crack tip stress intensity factors; engineering applications in stiffened structures, pressure vessels, plates, and shells. Letter grading. Mr. Gupta (Sp)

M257A. Elastodynamics. (4) (Same as Earth and Space Sciences M224A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves in unbounded isotropic, anisotropic, and dissipative solids. Half-space problems. Guided waves in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading. Mr. Mal (Sp)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assignments in research problems leading to term paper or oral presentation (possible help from guest lecturers). Letter grading. Mr. Smith (Sp)

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 of solids. 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 be repeated for credit. S/U grading.

261A. Energy and Computational Methods in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Review of theory of linear elasticity and reduced structural theories (rods, plates, and shells). Calculus of variations. Virtual work. Minimum and stationary variational principles. Variational approximation methods. Weighted residual methods, weak forms. Static finite element method. Isoparametric elements, beam and plate elements. Numerical quadrature. Letter grading. Mr. Bendiksen (F)

261B. Computational Mechanics of Solids and Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 261A. Variational formulation and computer implementation of linear elastic finite element method. Error analysis and convergence. Methods for large displacements, large deformations, and other geometric nonlinearities. Solution techniques for nonlinear equations. Finite element method for dynamics of solids and structures. Time integration algorithms. Term projects using digital computers. Letter grading. Mr. Klug (W)

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 166C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macro analysis, including classical lamination theory, shear lag theory, concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and bimorph. Letter grading. Mr. Carman (W)

263A. Analytical Foundations of Motion Controllers. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: courses 163A, 294. Theory of motion control for modern computer-controlled machines; multiaxis computer-controlled machines; machine kinematics and dynamics; multiaxis motion coordination; coordinated motion with desired speed and acceleration; jerk analysis; motion command generation; theory and design of controller interpolators; motion trajectory design and analysis; geometry-speed-sampling time relationships. Letter grading. Mr. Yang (W)

263B. Spacecraft Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Recommended: course 255B. Modeling, dynamics, and stability of spacecraft; spinning and dual-spin spacecraft dynamics; spinup through resonance, spinning rocket dynamics; environmental torques in space, modeling and model reduction of flexible space structures. Letter grading. Mr. Frazzoli (Sp, alternate years)

263C. Mechanics and Trajectory Planning of Industrial Robots. (4) Lecture, four hours; outside study, eight hours. Requisite: course 163A. Theory and implementation of industrial robots. Design considerations. Kinematic structure modeling, trajectory planning, and system dynamics. Differential motion and static forces. Individual student study projects. Letter grading. Mr. Yang (W)

263D. Advanced Robotics. (4) Lecture, four hours; outside study, eight hours. Recommended preparation: courses 155, 163C, 171A, 263C. Motion planning and control of articulated dynamic systems: nonlinear joint control, experiments in joint control and multi-axes coordination, multibody dynamics, trajectory planning, motion optimization, dynamic performance and manipulator design, kinematic redundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading. Mr. Hahn (Sp)

M269A. Dynamics of Structures. (4) (Same as Civil Engineering M237A.) Lecture, four hours; outside study, eight hours. Requisite: course 169A. Principles of dynamics. Determination of normal modes and frequencies by differential and integral equation solutions. Transient and steady state response. Emphasis on derivation and solution of governing equations using matrix formulation. Letter grading. Mr. Bendiksen (W)

269B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Analysis of linear and nonlinear response of structures to dynamic loadings. Stresses and deflections in structures. Structural damping and self-induced vibrations. Letter grading. 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 171A or Electrical Engineering 141. 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. Gibson (Sp)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stabilizability, observability, and detectability solutions. Letter grading. Mr. Gibson (F)

M270C. Optimal Control. (4) (Same as Chemical Engineering M280C and Electrical Engineering M240C.) Lecture, four hours; outside study, eight hours. Requisite: course 270B. Applications of 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. Mr. Speyer (Sp)

271A. Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, 174. Probability space, random variables, stochastic processes, Brownian motion, Markov processes, stochastic integrals and differential equations, power spatial density, and Kolmogorov equations. Letter grading. Mr. Speyer (F)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W)

271C. Stochastic Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271B. Stochastic dynamic programming, certainty equivalence principle, separation theorem, information statistics; linear-quadratic-Gaussian problem, linear-exponential-Gaussian problem. Relationship between stochastic control and robust control. Letter grading. Mr. Speyer (Sp)

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical 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 stability. Liapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading. Mr. Shamma (Sp)

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M'Closkey (Sp)

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. Discussion of applications in mechanical and aerospace engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. 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 model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. Mr. Shamma (Sp)

M280. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Biomedical Engineering M250A and Electrical Engineering M250A.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M180L. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C-J. Kim (W)

280L. Microelectromechanical Systems (MEMS) Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisite: course 180. Hands-on micromachining. Mask layout, clean room procedure, lithography, oxidation, LPCVD coatings, evaporation, wet etchings (both isotropic and anisotropic), dry etchings, process monitoring. Students fabricate simple micromechanical devices by both surface and bulk micromachining and test and characterize them. Letter grading. Mr. C-J. Kim (W)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Basic science issues in micro domain. Topics include micro fluid science, microscale heat transfer, mechanical behavior of microstructures, as well as dynamics and control of micro devices. Letter grading. Mr. Ho, Mr. C-J. Kim (F)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Biomedical Engineering M250B and Electrical Engineering M250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M280. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. C-J. Kim (Sp)

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 for engineering applications. Material characterization, mechanical/material properties, mechanical characterization. Topics include fundamentals of crystallography, anisotropic material properties, and mechanical behavior (e.g., strength/fracture/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. Ho (W, alternate years)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, M105A, 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 (F)

286. Molecular Dynamics Simulation. (4) Lecture, four hours; outside study, eight hours. Preparation: computer programming experience. Requisites: courses 182A, 182C. Introduction to basic concepts and methodologies of molecular dynamics simulation. Advantages and disadvantages of this approach for various situations. Emphasis on systems of engineering interest, especially microscale fluid mechanics, heat transfer, and solid mechanics problems. Letter grading. Mr. Kavehpour (W)

C287L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (2 to 4) Lecture, two hours; laboratory, two 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, nanocharacterization (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. Chen (Sp)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 14, Physics 17. Science and engineering of laser microscopic fabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (therma, mass, chemical, carrier, etc.) in laser microfabrication, state-of-the-art optics and instrumentation for laser microfabrication, applications such as rapid prototyping, surface modifications (physical/chemical), micromachines for three-dimensional MEMS (microelectromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter grading. Mr. Zhang (Sp)

289. Nanoscale Fabrication, Characterization, and Biodetection. (4) Lecture, two hours; laboratory, two hours. Requisites: courses M180, M180L. Introduction to cutting-edge knowledge and laboratory techniques about nanoscale fabrication, characterization, and biodetection, including basic physical, chemical, and biological principles in nano-areas; top-down and bottom-up (self-assembly) nanofabrication; nanocharacterization (AEM, SEM, etc.); nanoscale electric devices, circuits, and optical and electrochemical biosensors. Training provided in multidisciplinary areas of nanotechnology; students encouraged to create their own ideas in self-designed experiments. Letter grading. Mr. Chen (W)

293. Quality Engineering in Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 174. Quality engineering concepts and approaches. Taguchi methods of robust technology development and off-line control. Quality loss function, signal-to-noise ratio, and orthogonal arrays. Parametric design of products and production processes. Tolerance design. Online quality control systems. Decision making in quality engineering. Letter grading. Mr. Yang (W)

294. Computational Geometry for Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 194. Computational geometry for design and manufacturing, with special emphasis on curve and surface theory, geometric modeling of curves and surfaces, B-splines and NURBS, composite curves and surfaces, computing methods for surface design and manufacture, and current research topics in computational geometry for CAD/CAM systems. Letter grading. Mr. Yang (W)

295A. Computer-Aided Manufacturing. (4) (Formerly numbered 295.) Lecture, four hours; outside study, eight hours. Preparation: course 163A or 185. Requisite: course 94. Concepts, methods, and elements of computer-aided manufacturing. Planning and control of manufacturing systems. Group technology and computer-aided process planning. Design and modeling of flexible manufacturing systems. Computer-aided manufacturing. Letter grading. Mr. Zhang (F)

295B. Internet-Based Collaborative Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 94, 184. Exploration of advanced state-of-the-art concepts in Internet-based collaborative design, including software environments to connect designers over Internet, networked variable media graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mobile device-based systems, and multifunctional design collaboration and software tools to support it. Letter grading. Mr. Gadh (F)

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 (F)

296A. Damage and Failure of Materials in Mechanical Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course 156A, Materials Science 143A. Role of failure prevention in mechanical design and case studies. Mechanics and physics of material imperfections: voids, dislocations, cracks, and inclusions. Statistical and deterministic design methods. Plastic, fatigue, and creep damage. Letter grading. Mr. Ghoniem (Sp, alternate years)

296B. Thermochemical Processing of Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 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 (F)

297. Composites Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisites: course 166C, Materials Science 151. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading. Mr. Hahn (Sp)

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. Mr. Shamma (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 the University. May be repeated for credit. S/U grading. Mr. Mingori (F,W,Sp)

474B. Concurrent Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: Materials Science 474A. Product design, CAD/CAM, engineering analysis integration, project management. Letter grading. Mr. Hahn (W)

474C. Total Quality Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 474B. Total quality management, statistics, probability, off-line quality control, online quality control, quality inspection. Letter grading. Mr. Hahn (Sp)

475B. Automation. (4) Lecture, four hours; outside study, eight hours. Requisite: Materials Science 475A. Automatic control of single devices and processes for manufacturing automation. Integrated automation design. Introduction to control, digital control, and rule-based systems. Sensors and actuators used in manufacturing processes. Robotics and multiaxis machine tools. Integration of computer-controlled systems and control hardware. Letter grading. (W)

476. Integrated Manufacturing Engineering (IME) Seminar Series. (1) Lecture, one hour. Lectures by engineers in executive positions to provide management perspectives in manufacturing enterprises. Current manufacturing techniques and integrated product development efforts by industry experts. S/U grading. (F,W,Sp)

478. Integrated Manufacturing Engineering (IME) Group Project Studies. (1 to 12) Lecture, one hour; group projects, one to 12 hours. Teams of students perform detailed analyses to address problems presented and implement manufacturing solutions within industrial settings. S/U grading. (F,W,Sp)

497A-497B. Field Project in Manufacturing Engineering. (4-4) Lecture, two hours. Teams of students perform detailed system analysis and plan design of manufacturing engineering systems at various manufacturing plants. In Progress (497A) and S/U or letter (497B) grading. Mr. Yang (W, 497A; Sp, 497B)

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

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

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

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

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

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

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 24.

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

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

87. Introduction to Engineering Disciplines. (4) (Formerly numbered 97.) 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 the U.S. technological work force. P/NP grading. Mr. Jacobsen (F)

95. Ethical and Professional Issues in Engineering and Computer Science. (4) Lecture, four hours; discussion, one hour. Selected lectures, discussions, and oral and written reports related to profession of engineering. Lectures by practicing engineers, case studies, and small group projects on issues that involve conflicting demands on society. Letter grading. Mr. O'Neill (F,W,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 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

183. Engineering and Society. (4) (Formerly numbered 193.) Lecture, four hours; discussion, one hour; outside study, seven hours. Limited to junior/senior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and on development of moral and ethical values. Contemporary environmental, biological, legal, and other issues created by new technologies. Letter grading. Mr. Jacobsen (F,W,Sp)

185. Art of Engineering Endeavors. (4) (Formerly numbered 195.) Lecture, four hours; discussion, one hour; outside study, 12 hours. Designed for seniors. Importance of group dynamics in engineering practice. Teamwork and effective group skills in engineering environments. Organization and control of multidisciplinary complex engineering projects. Forms of leadership and qualities and characteristics of effective leaders. How engineering, computer sciences, and technology relate to major ethical and social issues. Societal demands on practice of engineering. Letter grading. Mr. Jacobsen (F)

195. Internship Studies in Engineering. (4) (Formerly numbered 195I.) Tutorial, four hours. Limited to juniors/seniors. 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. Mr. Jacobsen (F,W,Sp)

Graduate Courses

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading. Mr. Jacobsen

201. Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading. (W)

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

470A-470D. The Engineer in the 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 management 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.

471A-471B-471C. The Engineer in the General Environment. (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading; In Progress (471B) and S/U or letter (471C) grading.

472A-472D. The Engineer in the 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 the 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 a 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 a goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as a 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. (F)

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.

Research Centers, Laboratories, and Institutes

Center for Embedded Networked Sensing

National Science Foundation Science and Technology Center

Deborah Estrin (Computer Science), *Director*; http://www.cens.ucla.edu

UCLA's Center for Embedded Networked Sensing (CENS) is a major research enterprise developing wireless sensor systems and applying this revolutionary technology to radically transform critical scientific and societal applications. Expanding on the concept of the Internet, these large-scale distributed systems, composed of smart wireless sensors and actuators embedded in the physical world, will eventually connect the entire physical world to the virtual world.

Embedded networked sensing systems can reveal previously unobservable phenomena through the use of adaptive, self-configuring wireless systems that enable spatially and temporally dense monitoring of challenging physical environments. This new technology will revolutionize biological and physical sciences, including tracking ecosystem dynamics and large-scale, real-time monitoring of seismic events.

The center forms a cornerstone for new transdisciplinary partnerships, such as creating innovative formats for film, theater, and digital media arts and enabling remote monitoring of patients' health. CENS hopes to have a significant impact on gender disparities in science and engineering at UCLA, providing increased hands-on research opportunities for undergraduate students, and middle and high school students.

Center for Nanoscience Innovation for Defense

Defense Advanced Research Project Agency/Defense MicroElectronics Activity

Eli Yablonovitch (Electrical Engineering), *Director*

The Center for Nanoscience Innovation for Defense (CNID) was established to facilitate the rapid transition of research innovation in the nanosciences into applications for the defense sector. With nationally renowned faculty employing interdisciplinary approaches, the center brings discovery and innovation in nanoscience and nanoengineering to America's industries for the purpose of defense.

The center's research program seeks to understand and thereby control nanometer-scale systems for advanced technology. Research at UCLA focuses on four areas: quantum telecommunication nanodevices, development of a single-electron-spin microscope, photonic crystal nanooptical structures and circuits, and molecular level electronic and mechanical devices.

Funding through CNID will help equip the California NanoSystems Institute with state-of-the-art high-tech instrumentation, and also support graduate fellowships that will attract the best graduate students worldwide to advance nanoscience and nanotechnology research. Those students will be not only the nanoscience university researchers of the future, but also the nanotechnology talent for high-tech American businesses.

Center for Scalable and Integrated Nanomanufacturing

National Science Foundation Nanoscale Science and Engineering Center

Xiang Zhang, *Director (UC Berkeley)*; Eli Yablonovitch, (Electrical Engineering), *Co-Director*; http://www.sinam.ucla.edu

The promise that nanotechnology holds for industries ranging from semiconductors to health care to national defense has largely been held back by the lack of manufacturing platforms that allow complex nanoengineered products and systems to be adopted on a mass scale. UCLA's Center for Scalable and Integrated Nanomanufacturing (SINAM) is bridging the gap between scientific research and economically feasible manufacturing solutions.

SINAM researchers will combine fundamental science and nanomanufacturing technology in new ways, transforming laboratory science into industrial applications in nanoelectronics and biomedicine. A multidisciplinary team of researchers will devise commercial nanomanufacturing tool designs and build them into systems that will enable cost-effective nanomanufacturing. A better understanding of the nano world will lead to more powerful microscopes, groundbreaking nanofabrication technologies, and exciting new applications in information technology and medicine.

Flight Systems Research Center

A.V. Balakrishnan (Electrical Engineering), *Director*; http://fsrc.ee.ucla.edu

The Flight Systems Research Center, established in 1985 under a Memorandum-of-Agreement with the NASA Ames/Dryden Flight Research Facility, is devoted to interdisciplinary research in flight systems and related technologies. Faculty from the Computer Science, Electrical Engineering, Mathematics, and Mechanical and Aerospace Engineering Departments are currently associated with the center. Current research projects include:

- Viscous flow simulation of boundary layer instability and transition in supersonic swept wing flows
- Embedded optical sensor research with applications to flight
- Research studies for flight systems of the future
- Aircraft finite element model validation based on ground vibration test data
- Development of a compact ultrasonic piezohydraulic actuator for control surface articulation
- Support of the development of a neural net flight air data system
- Development of probabilistic risk assessment models of UAVs
- Self-aware sensor networks
- Shape memory alloys for trailing-edge wing flaps or trim tabs
- CFD calculations of shock oscillations in transonic flow over active aeroelastic wings
- In-flight leak detection systems
- Control of high speed jet mixing and reaction processes
- Mathematical theory of aeroelasticity
- Application of stochastic filtering and control methodology to the optimization of wind turbine control design

Functional Engineered Nano Architectonics Focus Center

Microelectronic Advanced Research Corporation Focus Center

Kang Wang (Electrical Engineering), *Director*; Bruce Dunn (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 will 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 will explore 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 will allow them to extend semiconductor technology further into the realm of the nanoscale.

Institute for Cell Mimetic Space Exploration

A NASA University Research, Engineering, and Technology Institute

Chih-Ming Ho (Mechanical and Aerospace Engineering), *Director*; Carlo Montemagno (Bioengineering), *Co-Director*; http://www.cmise.ucla.edu

The Institute for Cell Mimetic Space Exploration (CMISE) is realizing a unique approach by fusing biotechnology, nanotechnology, and information science to enrich the development of revolutionary application-specific technologies. For example, a cell fuses genetic processes with nanoscale sensors and actuators to result in an efficient, autonomous micro "factory." The basic processes that occur at the molecular level have opened up a world where the integration of individual components can eventually derive higher-order functionalities or emergent properties.

The fusion of biotechnology, nanotechnology, and informatics will culminate in systemic architectures that will rival those that have taken millions of years to come to fruition in nature. CMISE researchers also hope to achieve a fundamental comprehension of how the interplay of these three areas can be manipulated on the molecular level to produce enhanced, emergent properties.

CMISE is organized into four interdisciplinary research groups: energetics, metabolics, systematics, and CMISESat. The energetics group harnesses and transforms energy across a range of disciplines, while the metabolics team develops nano/micro systems for single-cell metabolism study and network reconstruction of radiation damage to cells. The systematics group enables intelligent cell mimetic systems, and monitors and controls artificial and biological subsystems. The CMISESat team provides the space testbed environment for validation and demonstration of emerging CMISE technologies.

Institute of Plasma and Fusion Research

Mohamed A. Abdou (Engineering) and Alfred Wong (Physics), *Codirectors*; http://www.ipfr.ucla.edu

The Institute of Plasma and Fusion Research is a UCLA organized research unit dedicated to research into plasma physics, fusion energy, and the applications of plasmas in other areas of science and engineering. Students, professional research staff, and faculty, generally working in groups, study basic laboratory plasmas, plasma/fusion confinement experiments, fusion engineering and nuclear technology, computer simulations and the theory of plasmas, advanced plasma diagnostic development, laser/plasma interactions, and the use of plasma in applications ranging from particle accelerators to the processing of materials and surfaces used in microelectronics or for coatings.

The institute and its members are affiliated with both the College of Letters and Science and the Henry Samueli School of Engineering and Applied Science. Faculty, staff, and students come from the Electrical Engineering, Mechanical and Aerospace Engineering, and Physics and Astronomy Departments.

The overall UCLA effort in this field is quite broad. On a disciplinary basis, the program can be divided into the following categories:

- Astrophysical and space plasmas
- Basic plasma experiments
- Computer simulation of plasmas
- Fluid and thermal engineering sciences for fusion technology
- Fusion confinement experiments and devices
- Fusion engineering and reactor physics for magnetic and inertial fusion
- Fusion nuclear technology
- Plasma/surface interactions, coatings and surface material processing
- Radiation damage and materials science

Magnetic confinement fusion experiments include a tokamak machine, special confinement devices, and machines for basic plasma studies. Experiments have been built to simulate and study space plasmas and to investigate laser/plasma interactions as a means of accelerating particles for high-energy physics. Plasma sources are used in experiments to study plasma/material interactions research and as sources for the production of thin films and coatings. Theoretical and computer simulation research aims at understanding plasma behavior, ranging from plasmas in space to fusion plasmas. Fusion engineering activities include development of new diagnostics and RF power sources and the study of materials behavior, fusion nuclear technology, and fusion reactors.

Research in plasma physics and fusion energy is an exciting area of modern technology. Last year, UCLA's plasma and fusion programs received more than $12 million in research grants from several federal agencies, from the National Laboratories, and from industry. The largest amount of funding comes from the U.S. Department of Energy, but substantial resources are received from the National Science Foundation, NASA, and research offices of the U.S. Department of Defense.

B.S. in Aerospace Engineering Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Mathematics 32A – Calculus of Several Variables	4
Mechanical and Aerospace Engineering 20 – Programming with Numerical Methods Applications	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
SOPHOMORE YEAR	
1st Quarter	
Mathematics 32B – Calculus of Several Variables	4
Physics 1C – Electrodynamics, Optics, and Special Relativity	5
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	5
2nd Quarter	
Materials Science and Engineering 14 – Science of Engineering Materials	4
Mathematics 33A – Linear Algebra and Applications	4
Mechanical and Aerospace Engineering M105A – Introduction to Engineering Thermodynamics	4
HSSEAS GE Elective*	5
3rd Quarter	
Mathematics 33B – Differential Equations	4
Mechanical and Aerospace Engineering 101 – Statics and Strength of Materials	4
Mechanical and Aerospace Engineering 103 – Elementary Fluid Mechanics	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 100 – Electrical and Electronic Circuits	4
Mechanical and Aerospace Engineering 102 – Dynamics of Particles and Rigid Bodies	4
Mechanical and Aerospace Engineering 105D – Transport Phenomena	4
Mechanical and Aerospace Engineering 182A – Mathematics of Engineering	4
2nd Quarter	
Mechanical and Aerospace Engineering 107/107L – Introduction to Modeling and Analysis of Dynamic Systems/Laboratory	4
Mechanical and Aerospace Engineering 150A – Intermediate Fluid Mechanics	4
Mechanical and Aerospace Engineering 157 – Basic Mechanical Engineering Laboratory	4
HSSEAS GE Elective*	4
3rd Quarter	
Mechanical and Aerospace Engineering 150B – Aerodynamics	4
Mechanical and Aerospace Engineering 171A – Introduction to Feedback and Control Systems	4
Aerospace Engineering Elective†	4
Mathematics Elective*	4
SENIOR YEAR	
1st Quarter	
Mechanical and Aerospace Engineering 150P – Aircraft Propulsion Systems	4
Mechanical and Aerospace Engineering 154S – Flight Mechanics, Stability, and Control of Aircraft	4
Mechanical and Aerospace Engineering 161A (Introduction to Astronautics) or 169A (Introduction to Mechanical Vibrations)	4
Mechanical and Aerospace Engineering 166A – Analysis of Flight Structures	4
2nd Quarter	
Mechanical and Aerospace Engineering 154A – Preliminary Design of Aircraft	4
Aerospace Engineering Electives (2)†	8
HSSEAS GE Elective*	4
3rd Quarter	
Mechanical and Aerospace Engineering 154B – Design of Aerospace Structures	4
Mechanical and Aerospace Engineering 157A – Fluid Mechanics and Aerodynamics Laboratory	4
Aerospace Engineering Elective†	4
HSSEAS GE Elective*	5
TOTAL	**191**

*Students should contact the Office of Academic and Student Affairs for approved elective lists in the categories of mathematics and HSSEAS GE (see page 21 for details).

†A total of 16 units of aerospace engineering electives (four courses) is required; electives must be selected so that the program contains a total of at least 24 design units.

B.S. in Bioengineering Curriculum

FRESHMAN YEAR	**UNITS**
1st Quarter	
Bioengineering 1*/1L* – Physics for Bioengineers I/Laboratory I	7
Chemistry and Biochemistry 14A** – Atomic and Molecular Structure, Equilibria, Acids, and Bases	4
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Bioengineering 2*/2L* – Physics for Bioengineers II/Laboratory II	7
Bioengineering 10 – Introduction to Bioengineering	2
Chemistry and Biochemistry 14B** – Thermodynamics, Electrochemistry, Kinetics, and Organic Chemistry	4
Mathematics 31B – Integration and Infinite Series	4
3rd Quarter	
Bioengineering 3*/3L – Physics for Bioengineers III/Laboratory III	7
Chemistry and Biochemistry 14C** – Structure of Organic Molecules	4
Mathematics 32A – Calculus of Several Variables	4
SOPHOMORE YEAR	
1st Quarter	
Bioengineering 100 – Bioengineering Fundamentals	4
Chemistry and Biochemistry 14BL** – General and Organic Chemistry Laboratory I	3
Mathematics 32B – Calculus of Several Variables	4
English Composition 3 – English Composition, Rhetoric, and Language	5
2nd Quarter	
Chemistry and Biochemistry 14CL** – General and Organic Chemistry Laboratory II	4
Mathematics 33A – Linear Algebra and Applications	4
Mechanical and Aerospace Engineering 20 – Programming with Numerical Methods Applications	4
HSSEAS GE Elective†	5
3rd Quarter	
Chemical Engineering M105A – Introduction to Engineering Thermodynamics	4
Chemistry and Biochemistry 14D** – Organic Reactions and Pharmaceuticals	4
Life Sciences 2 – Cells, Tissues, and Organs	5
Mathematics 33B – Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A – Momentum Transfer	4
Chemistry and Biochemistry 110A – Physical Chemistry: Chemical Thermodynamics	4
Chemistry and Biochemistry 153A – Biochemistry: Introduction to Structure, Enzymes, and Metabolism	4
Life Sciences 3 – Introduction to Molecular Biology	5
2nd Quarter	
Bioengineering 110 – Biotransport and Bioreaction Processes	4
Chemistry and Biochemistry 156 – Physical Biochemistry	4
Electrical Engineering 102 (Systems and Signals) or Mathematics 115A (Linear Algebra)	4
Life Sciences 4 – Genetics	5
3rd Quarter	
Bioengineering 120 – Biomedical Transducers	4
Biomedical Engineering M186B – Computational Systems Biology: Modeling and Simulation of Biological Systems	5
Molecular, Cell, and Developmental Biology M140 – Cell Biology: Cell Cycle	5
SENIOR YEAR	
1st Quarter	
Bioengineering 176 – Principles of Biocompatibility	4
Bioengineering 180/180L – System Integration in Biology, Engineering, and Medicine I/Laboratory	7
Bioengineering 182 – Bioengineering Capstone Design I	2
HSSEAS GE Elective†	5
2nd Quarter	
Bioengineering 181/181L – System Integration in Biology, Engineering, and Medicine II/Laboratory	7
Bioengineering 182B – Bioengineering Capstone Design II	2
Biomedical Engineering Elective‡	4
HSSEAS GE Elective†	4
3rd Quarter	
Bioengineering 165 – Bioethics and Regulatory Policies in Bioengineering	2
Bioengineering 182C – Bioengineering Capstone Design III	2
Biomedical Engineering Elective‡	4
HSSEAS GE Electives (2)†	10
TOTAL	**198**

*Physics 1A, 1B, 1C (or Electrical Engineering 1), 4AL, and 4BL may be substituted for courses 1, 1L, 2, 2L, and 3.
**Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, and 30B may be substituted for the Chemistry and Biochemistry 14 series.
†See page 21 for details.
‡See page 25 for list of approved electives.

B.S. in Chemical Engineering Curriculum

FRESHMAN YEAR	**UNITS**
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Chemistry and Biochemistry 30A – Chemical Dynamics and Reactivity: Introduction to Organic Chemistry	4
Chemistry and Biochemistry 30AL – General Chemistry Laboratory II	4
Mathematics 32A – Calculus of Several Variables	4
Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory	7
SOPHOMORE YEAR	
1st Quarter	
Chemical Engineering 100 – Fundamentals of Chemical and Biomolecular Engineering	4
Chemistry and Biochemistry 30B/30BL – Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory I	7
Mathematics 32B – Calculus of Several Variables	4
Physics 1C – Electrodynamics, Optics, and Special Relativity	5
2nd Quarter	
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (Programming with Numerical Methods Applications)	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Electives (2)*	10
3rd Quarter	
Chemical Engineering M105A – Introduction to Engineering Thermodynamics	4
Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A – Momentum Transfer	4
Chemical Engineering 109 – Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 171 – Intermediate Inorganic Chemistry	4
Electrical Engineering 100 – Electrical and Electronic Circuits	4
2nd Quarter	
Chemical Engineering 101B – Heat Transfer	4
Chemical Engineering 102 – Chemical Engineering Thermodynamics	4
Chemistry and Biochemistry 113A – Physical Chemistry: Introduction to Quantum Mechanics	4
Chemistry Elective†	4
3rd Quarter	
Chemical Engineering 101C – Mass Transfer	4
Chemical Engineering 103 – Separation Processes	4
Chemical Engineering 104A – Chemical Engineering Laboratory I	6
HSSEAS GE Elective*	5
SENIOR YEAR	
1st Quarter	
Chemical Engineering 104B – Chemical Engineering Laboratory II	6
Chemical Engineering 106 – Chemical Reaction Engineering	4
Chemistry Elective†	4
HSSEAS GE Elective*	4
2nd Quarter	
Chemical Engineering 107 – Process Dynamics and Control	4
Chemical Engineering 108A – Process Economics and Analysis	4
Chemical Engineering Elective‡	4
HSSEAS GE Elective*	4
3rd Quarter	
Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis	4
Chemical Engineering Elective‡	4
Chemistry Elective†	4
TOTAL	**202**

*See page 21 for details.
†Chemistry elective can be any upper division chemistry course except Chemistry and Biochemistry 110A and should be selected in consultation with adviser; one chemistry elective may be replaced by any upper division life or physical sciences course with approval of adviser. Chemistry and Biochemistry 110B is highly recommended.
‡Suggested electives include Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C125, C140.

B.S. in Chemical Engineering
Bioengineering Option Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B – Chemical Energetics and Change	4
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
HSSEAS GE Elective*	5
3rd Quarter	
Chemistry and Biochemistry 20L – General Chemistry Laboratory	3
Chemistry and Biochemistry 30A – Chemical Dynamics and Reactivity: Introduction to Organic Chemistry	4
Mathematics 32A – Calculus of Several Variables	4
Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory	7
SOPHOMORE YEAR	
1st Quarter	
Chemical Engineering 100 – Fundamentals of Chemical and Biomolecular Engineering	4
Chemistry and Biochemistry 30AL – General Chemistry Laboratory II	4
Mathematics 32B – Calculus of Several Variables	4
Physics 1C/4BL – Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory	7
2nd Quarter	
Chemical Engineering M105A – Introduction to Engineering Thermodynamics	4
Chemistry and Biochemistry 30B/30BL – Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory I	7
Civil and Environmental Engineering 15 – Introduction to Computing for Civil Engineers	4
Mathematics 33A – Linear Algebra and Applications	4
3rd Quarter	
Chemistry and Biochemistry 153A – Biochemistry: Introduction to Structure, Enzymes, and Metabolism	4
Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids	4
Life Sciences 2 – Cells, Tissues, and Organs	5
Mathematics 33B – Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A – Momentum Transfer	4
Chemical Engineering 109 – Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 156 – Physical Biochemistry	4
Life Sciences 3 – Introduction to Molecular Biology	5
2nd Quarter	
Chemical Engineering 101B – Heat Transfer	4
Chemical Engineering 102 – Chemical Engineering Thermodynamics	4
Life Sciences 4 (Genetics) or Microbiology, Immunology, and Molecular Genetics 101 (Introductory Microbiology)	4 or 5
HSSEAS GE Elective*	5
3rd Quarter	
Chemical Engineering 101C – Mass Transfer	4
Chemical Engineering 103 – Separation Processes	4
Chemical Engineering 104A – Chemical Engineering Laboratory I	6
HSSEAS GE Elective*	5
SENIOR YEAR	
1st Quarter	
Chemical Engineering 104B – Chemical Engineering Laboratory II	6
Chemical Engineering 106 – Chemical Reaction Engineering	4
Electrical Engineering 100 – Electrical and Electronic Circuits	4
HSSEAS GE Elective*	4
2nd Quarter	
Chemical Engineering 107 – Process Dynamics and Control	4
Chemical Engineering 108A – Process Economics and Analysis	4
Bioengineering Elective†	4
Biology Elective‡	4
3rd Quarter	
Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis	4
Bioengineering Elective†	4
HSSEAS GE Elective*	5
TOTAL	**204 or 205**

*See page 21 for details.
†Recommended electives are Chemical Engineering C115, C125, CM145. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.
‡Biology elective is selected from any upper division course in Ecology and Evolutionary Biology or Molecular, Cell, and Developmental Biology or Microbiology, Immunology, and Molecular Genetics, provided the course requires one year of chemistry as a requisite.

B.S. in Chemical Engineering
Biomedical Engineering Option Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B – Chemical Energetics and Change	4
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
HSSEAS GE Elective*	5
3rd Quarter	
Chemistry and Biochemistry 20L – General Chemistry Laboratory	3
Chemistry and Biochemistry 30A – Chemical Dynamics and Reactivity: Introduction to Organic Chemistry	4
Mathematics 32A – Calculus of Several Variables	4
Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory	7
SOPHOMORE YEAR	
1st Quarter	
Chemical Engineering 100 – Fundamentals of Chemical and Biomolecular Engineering	4
Chemistry and Biochemistry 30AL – General Chemistry Laboratory II	4
Mathematics 32B – Calculus of Several Variables	4
Physics 1C/4BL – Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory	7
2nd Quarter	
Chemistry and Biochemistry 30B/30BL – Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory I	7
Civil and Environmental Engineering 15 – Introduction to Computing for Civil Engineers	4
Life Sciences 1 – Evolution, Ecology, and Biodiversity	5
Mathematics 33A – Linear Algebra and Applications	4
3rd Quarter	
Chemical Engineering M105A – Introduction to Engineering Thermodynamics	4
Chemistry and Biochemistry 153A – Biochemistry: Introduction to Structure, Enzymes, and Metabolism	4
Life Sciences 2 – Cells, Tissues, and Organs	5
Mathematics 33B – Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A – Momentum Transfer	4
Chemical Engineering 109 – Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 156 – Physical Biochemistry	4
Life Sciences 3 – Introduction to Molecular Biology	5
2nd Quarter	
Chemical Engineering 101B – Heat Transfer	4
Chemical Engineering 102 – Chemical Engineering Thermodynamics	4
Life Sciences 4 (Genetics) or Microbiology, Immunology, and Molecular Genetics 101 (Introductory Microbiology)	4 or 5
HSSEAS GE Elective*	5
3rd Quarter	
Chemical Engineering 101C – Mass Transfer	4
Chemical Engineering 103 – Separation Processes	4
Chemical Engineering 104A – Chemical Engineering Laboratory I	6
HSSEAS GE Elective*	5
SENIOR YEAR	
1st Quarter	
Chemical Engineering 104B – Chemical Engineering Laboratory II	6
Chemical Engineering 106 – Chemical Reaction Engineering	4
Biology Elective and Laboratory†	6
2nd Quarter	
Chemical Engineering 107 – Process Dynamics and Control	4
Chemical Engineering 108A – Process Economics and Analysis	4
Biomedical Engineering Elective‡	4
HSSEAS GE Elective*	4
3rd Quarter	
Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis	4
Biomedical Engineering Elective‡	4
HSSEAS GE Elective*	5
TOTAL	**203 or 204**

*See page 21 for details.
†Biology elective is selected from any upper division course in Ecology and Evolutionary Biology or Molecular, Cell, and Developmental Biology or Microbiology, Immunology, and Molecular Genetics, provided the course requires one year of chemistry as a requisite.
‡Recommended electives are Chemical Engineering C115, C125, CM145. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.

B.S. in Chemical Engineering
Environmental Option Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Chemistry and Biochemistry 30A/30AL – Chemical Dynamics and Reactivity: Introduction to Organic Chemistry/Laboratory II	8
Mathematics 32A – Calculus of Several Variables	4
Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory	7
SOPHOMORE YEAR	
1st Quarter	
Chemical Engineering 100 – Fundamentals of Chemical and Biomolecular Engineering	4
Chemistry and Biochemistry 30B/30BL – Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory I	7
Mathematics 32B – Calculus of Several Variables	4
Physics 1C – Electrodynamics, Optics, and Special Relativity	5
2nd Quarter	
Atmospheric and Oceanic Sciences 104 – Fundamentals of Air and Water Pollution	4
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (Programming with Numerical Methods Applications)	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	5
3rd Quarter	
Chemical Engineering M105A – Introduction to Engineering Thermodynamics	4
Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A – Momentum Transfer	4
Chemical Engineering 109 – Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 171 – Intermediate Inorganic Chemistry	4
Electrical Engineering 100 – Electrical and Electronic Circuits	4
2nd Quarter	
Chemical Engineering 101B – Heat Transfer	4
Chemical Engineering 102 – Chemical Engineering Thermodynamics	4
Chemistry and Biochemistry 113A – Physical Chemistry: Introduction to Quantum Mechanics	4
Chemistry Elective†	4
3rd Quarter	
Chemical Engineering 101C – Mass Transfer	4
Chemical Engineering 103 – Separation Processes	4
Chemical Engineering 104A – Chemical Engineering Laboratory I	6
HSSEAS GE Elective*	5
SENIOR YEAR	
1st Quarter	
Chemical Engineering 104B – Chemical Engineering Laboratory II	6
Chemical Engineering 106 – Chemical Reaction Engineering	4
Chemistry Elective†/HSSEAS GE Elective*	8
2nd Quarter	
Chemical Engineering 107 – Process Dynamics and Control	4
Chemical Engineering 108A – Process Economics and Analysis	4
Environmental Engineering Elective‡/HSSEAS GE Elective*	9
3rd Quarter	
Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis	4
Chemistry Elective†/HSSEAS GE Elective*	8
Environmental Engineering Elective‡	4
TOTAL	**206**

*See page 21 for details.

†Suggested advanced chemistry electives in the environmental field are Atmospheric and Oceanic Sciences M203A, Chemistry and Biochemistry 103, 110B, Ecology and Evolutionary Biology M127, and Environmental Health Sciences 240, 261. Other advanced chemistry courses may be selected in consultation with the faculty adviser.

‡Recommended electives are Chemical Engineering 113, C118, C119, C140. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.

B.S. in Chemical Engineering
Semiconductor Manufacturing Option Curriculum

FRESHMAN YEAR	**UNITS**
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Chemistry and Biochemistry 30A – Chemical Dynamics and Reactivity: Introduction to Organic Chemistry	4
Chemistry and Biochemistry 30AL – General Chemistry Laboratory II	4
Mathematics 32A – Calculus of Several Variables	4
Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory	7
SOPHOMORE YEAR	
1st Quarter	
Chemical Engineering 100 – Fundamentals of Chemical and Biomolecular Engineering	4
Chemistry and Biochemistry 30B/30BL – Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory I	7
Mathematics 32B – Calculus of Several Variables	4
Physics 1C – Electrodynamics, Optics, and Special Relativity	5
2nd Quarter	
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (Programming with Numerical Methods Applications)	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Electives (2)*	10
3rd Quarter	
Chemical Engineering M105A – Introduction to Engineering Thermodynamics	4
Materials Science and Engineering 14 – Science of Engineering Materials	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A – Momentum Transfer	4
Chemical Engineering 109 – Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 171 – Intermediate Inorganic Chemistry	4
Electrical Engineering 100 – Electrical and Electronic Circuits	4
2nd Quarter	
Chemical Engineering 101B – Heat Transfer	4
Chemical Engineering 102 – Chemical Engineering Thermodynamics	4
Chemistry and Biochemistry 113A – Physical Chemistry: Introduction to Quantum Mechanics	4
Materials Science and Engineering 120 – Physics of Materials	4
3rd Quarter	
Chemical Engineering 101C – Mass Transfer	4
Chemical Engineering 103 – Separation Processes	4
Chemical Engineering 104A – Chemical Engineering Laboratory I	6
HSSEAS GE Elective*	5
SENIOR YEAR	
1st Quarter	
Chemical Engineering 106 – Chemical Reaction Engineering	4
Electrical Engineering 2 – Physics for Electrical Engineers	4
Chemistry Elective†/Semiconductor Manufacturing Elective‡	8
2nd Quarter	
Chemical Engineering 107 – Process Dynamics and Control	4
Chemical Engineering 108A – Process Economics and Analysis	4
Chemistry Elective†/HSSEAS GE Elective*	8
3rd Quarter	
Chemical Engineering 104C/104CL – Semiconductor Processing/Laboratory	6
Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis	4
Semiconductor Manufacturing Elective‡/HSSEAS GE Elective*	8
TOTAL	**206**

*See page 21 for details.
†Chemistry elective can be any upper division chemistry course except Chemistry and Biochemistry 110A and should be selected in consultation with adviser; Chemistry and Biochemistry 110B is highly recommended.
‡Suggested electives include Chemical Engineering C112, 113, C114, C116, C118, C119, C140. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.

B.S. in Civil Engineering Curriculum

FRESHMAN YEAR	**UNITS**
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
Civil and Environmental Engineering 1 – Introduction to Civil Engineering	2
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Mathematics 32A – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
HSSEAS GE Elective*	5
SOPHOMORE YEAR	
1st Quarter	
Materials Science and Engineering 14 – Science of Engineering Materials	4
Mathematics 32B – Calculus of Several Variables	4
Physics 1C – Electrodynamics, Optics, and Special Relativity	5
Physics 4BL – Electricity and Magnetism Laboratory	2
2nd Quarter	
Civil and Environmental Engineering 15 – Introduction to Computing for Civil Engineers	4
Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids	4
Mathematics 33A – Linear Algebra and Applications	4
HSSEAS GE Elective*	4
3rd Quarter	
Mathematics 33B – Differential Equations	4
Mechanical and Aerospace Engineering 102 – Mechanics of Particles and Rigid Bodies	4
Mechanical and Aerospace Engineering 103 – Elementary Fluid Mechanics	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Civil and Environmental Engineering 120 – Principles of Soil Mechanics	4
Civil and Environmental Engineering 135A – Elementary Structural Analysis	4
Civil and Environmental Engineering 150 – Introduction to Hydrology	4
Civil and Environmental Engineering 153 – Introduction to Environmental Engineering Science	4
2nd Quarter	
Civil and Environmental Engineering 121 – Design of Foundations and Earth Structures	4
Civil and Environmental Engineering 130 – Elementary Structural Mechanics	4
Civil and Environmental Engineering 151 – Introduction to Water Resources Engineering	4
Mechanical and Aerospace Engineering M105A – Introduction to Engineering Thermodynamics	4
3rd Quarter	
Civil and Environmental Engineering 110 – Introduction to Probability and Statistics for Engineers	4
Electrical Engineering 103 – Applied Numerical Computing	4
Major Field Electives (2)†	8
SENIOR YEAR	
1st Quarter	
HSSEAS GE Elective*	5
Major Field Electives (2)†	8
2nd Quarter	
Mechanical and Aerospace Engineering 182A – Mathematics of Engineering	4
HSSEAS GE Elective*	4
Major Field Electives (2)†	8
3rd Quarter	
HSSEAS GE Elective*	5
Major Field Electives (2)†	8
TOTAL	**185**

*See page 21 for details.
†At least two major field electives must include a major design project (selected from Civil and Environmental Engineering 123, 135L, 144, 147, 157B, 157C, 157L), and at least 8 units of laboratory in at least two major field areas are required.

B.S. in Computer Science Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Computer Science 31 – Introduction to Computer Science I	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Computer Science 32 – Introduction to Computer Science II	4
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
HSSEAS GE Elective*	5
3rd Quarter	
Computer Science 33 – Introduction to Computer Organization	5
Mathematics 32A – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
SOPHOMORE YEAR	
1st Quarter	
Computer Science M51A or Electrical Engineering M16 – Logic Design of Digital Systems	4
Mathematics 32B – Calculus of Several Variables	4
Mathematics 61 – Introduction to Discrete Structures	4
HSSEAS GE Elective*	5
2nd Quarter	
Electrical Engineering 1 – Electrical Engineering Physics I	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	5
3rd Quarter	
Computer Science M152A or Electrical Engineering M116L – Introductory Digital Design Laboratory	2
Electrical Engineering 2 – Physics for Electrical Engineers	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Computer Science 131 – Programming Languages	4
Computer Science M151B or Electrical Engineering M116C – Computer Systems Architecture	4
Computer Science 180 – Introduction to Algorithms and Complexity	4
HSSEAS GE Elective*	4
2nd Quarter	
Computer Science M152B or Electrical Engineering M116D – Digital Design Project Laboratory	4
Computer Science 161 – Fundamentals of Artificial Intelligence	4
Minor #1	4
HSSEAS GE Elective*	4
3rd Quarter	
Computer Science 111 – Operating Systems Principles	4
Electrical Engineering 103† (Applied Numerical Computing) or Computer Science 170A (Mathematical Modeling and Methods for Computer Science)	4
Statistics 110A – Applied Statistics	4
Computer Science Elective	4
SENIOR YEAR	
1st Quarter	
Computer Science 112 – Computer System Modeling Fundamentals	4
Computer Science 118 – Computer Network Fundamentals	4
Computer Science 181 – Introduction to Formal Languages and Automata Theory	4
Computer Science Elective	4
2nd Quarter	
Computer Science 132 – Compiler Construction	4
Computer Science Elective	4
Minor #2	4
3rd Quarter	
Computer Science Electives (2)	8
Minor #3	4
TOTAL	**182**

*See page 21 for details.
†Students who select Electrical Engineering 103 may not receive credit for Mathematics 151A under the technical minor.

B.S. in Computer Science and Engineering Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
Computer Science 31 – Introduction to Computer Science I	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Computer Science 32 – Introduction to Computer Science II	4
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
HSSEAS GE Elective*	5
3rd Quarter	
Computer Science 33 – Introduction to Computer Organization	5
Mathematics 32A – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
SOPHOMORE YEAR	
1st Quarter	
Computer Science M51A or Electrical Engineering M16 – Logic Design of Digital Systems	4
Mathematics 32B – Calculus of Several Variables	4
Mathematics 61 – Introduction to Discrete Structures	4
HSSEAS GE Elective*	5
2nd Quarter	
Electrical Engineering 1 – Electrical Engineering Physics I	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	5
3rd Quarter	
Computer Science M152A or Electrical Engineering M116L – Introductory Digital Design Laboratory	2
Electrical Engineering 2 – Physics for Electrical Engineers	4
Mathematics 33B – Differential Equations	4
Statistics 110A – Applied Statistics	4
JUNIOR YEAR	
1st Quarter	
Computer Science M151B or Electrical Engineering M116C – Computer Systems Architecture	4
Electrical Engineering 10 – Circuit Analysis I	4
Electrical Engineering 103 – Applied Numerical Computing	4
HSSEAS GE Elective*	5
2nd Quarter	
Computer Science 131 – Programming Languages	4
Computer Science 180 – Introduction to Algorithms and Complexity	4
Electrical Engineering 102 – Systems and Signals	4
Electrical Engineering 110 – Circuit Analysis II	4
3rd Quarter	
Computer Science 111 – Operating Systems Principles	4
Computer Science 181 – Introduction to Formal Languages and Automata Theory	4
Electrical Engineering 110L – Circuit Measurements Laboratory	2
Electrical Engineering 115A – Analog Electronic Circuits I	4
SENIOR YEAR	
1st Quarter	
Computer Science 118 – Computer Network Fundamentals	4
Computer Science M152B or Electrical Engineering M116D – Digital Design Project Laboratory	4
Electrical Engineering 115AL – Analog Electronics Laboratory I	2
Electrical Engineering 115C – Digital Electronic Circuits	4
Computer Science/Electrical Engineering Elective	4
2nd Quarter	
Computer Science Elective	4
Computer Science Elective	4
Computer Science Elective	4
3rd Quarter	
Computer Science Elective	4
HSSEAS GE Elective*	4
HSSEAS GE Elective*	4
TOTAL	**186**

*See page 21 for details.

B.S. in Electrical Engineering Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
Computer Science 31 – Introduction to Computer Science I	4
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Computer Science 32 – Introduction to Computer Science II	4
Mathematics 31B – Integration and Infinite Series	4
HSSEAS GE Elective*	4
3rd Quarter	
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 32A – Calculus of Several Variables	4
Physics 1A – Mechanics	5
HSSEAS GE Elective*	5
SOPHOMORE YEAR	
1st Quarter	
Mathematics 32B – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
HSSEAS GE Elective*	5
2nd Quarter	
Electrical Engineering 1 – Electrical Engineering Physics I	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	5
3rd Quarter	
Electrical Engineering 2 – Physics for Electrical Engineers	4
Electrical Engineering M16 or Computer Science M51A – Logic Design of Digital Systems	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 10 – Circuit Analysis I	4
Electrical Engineering 101 – Engineering Electromagnetics	4
Electrical Engineering 102 – Systems and Signals	4
Electrical Engineering 103 – Applied Numerical Computing	4
2nd Quarter	
Electrical Engineering 110 – Circuit Analysis II	4
Electrical Engineering 113 – Digital Signal Processing	4
Electrical Engineering 121B – Principles of Semiconductor Device Design	4
Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)	4
3rd Quarter	
Electrical Engineering 110L – Circuit Measurements Laboratory	2
Electrical Engineering 115A – Analog Electronic Circuits I	4
Electrical Engineering 161 – Electromagnetic Waves	4
Mechanical and Aerospace Engineering 182A – Mathematics of Engineering	4
Electrical Engineering Elective	4
SENIOR YEAR	
1st Quarter	
Electrical Engineering 115AL – Analog Electronics Laboratory I	2
Electrical Engineering 131A – Probability	4
Electrical Engineering 141– Principles of Feedback Control	4
Electrical Engineering 172 – Introduction to Lasers and Quantum Electronics	4
Electrical Engineering Elective	4
2nd Quarter	
Electrical Engineering 132A – Introduction to Communication Systems	4
Electrical Engineering Elective	4
Engineering Breadth†	4
3rd Quarter	
Electrical Engineering Electives (2)	8
HSSEAS GE Elective*	4
TOTAL	**190**

*See page 21 for details.
†Course must be selected from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A).

B.S. in Electrical Engineering
Biomedical Engineering Option Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Life Sciences 1 – Evolution, Ecology, and Biodiversity	5
Mathematics 32A – Calculus of Several Variables	4
Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory	7
SOPHOMORE YEAR	
1st Quarter	
Computer Science 31 – Introduction to Computer Science I	4
Life Sciences 2 – Cells, Tissues, and Organs	5
Mathematics 32B – Calculus of Several Variables	4
HSSEAS GE Elective*	5
2nd Quarter	
Electrical Engineering 1 – Electrical Engineering Physics I	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Electives (2)*	10
3rd Quarter	
Electrical Engineering 2 – Physics for Electrical Engineers	4
Electrical Engineering M16 or Computer Science M51A – Logic Design of Digital Systems	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 10 – Circuit Analysis I	4
Electrical Engineering 101 – Engineering Electromagnetics	4
Electrical Engineering 102 – Systems and Signals	4
Electrical Engineering 103 – Applied Numerical Computing	4
2nd Quarter	
Electrical Engineering 110 – Circuit Analysis II	4
Electrical Engineering 121B – Principles of Semiconductor Device Design	4
Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)	4
Mechanical and Aerospace Engineering 103 – Elementary Fluid Mechanics	4
3rd Quarter	
Electrical Engineering 110L – Circuit Measurements Laboratory	2
Electrical Engineering 113 – Digital Signal Processing	4
Mechanical and Aerospace Engineering M105A – Introduction to Engineering Thermodynamics	4
Mechanical and Aerospace Engineering 182A – Mathematics of Engineering	4
HSSEAS GE Elective*	4
SENIOR YEAR	
1st Quarter	
Electrical Engineering 131A – Probability	4
Electrical Engineering 141– Principles of Feedback Control	4
Electrical Engineering 161 – Electromagnetic Waves	4
Biomedical Engineering Elective†	4
2nd Quarter	
Chemistry and Biochemistry 30A – Chemical Dynamics and Reactivity: Introduction to Organic Chemistry	4
Chemistry and Biochemistry 30AL – General Chemistry Laboratory II	4
Electrical Engineering 115A – Analog Electronic Circuits I	4
Electrical Engineering 132A – Introduction to Communication Systems	4
3rd Quarter	
Electrical Engineering 114D – Speech and Image Processing Systems Design	4
Electrical Engineering 115AL – Analog Electronics Laboratory I	2
Life Sciences 3 – Introduction to Molecular Biology	5
Biomedical Engineering Elective†	4
Electrical Engineering Elective‡	4
TOTAL	**201**

*See page 21 for details.
†See counselor, 6426 Boelter Hall, for details.
‡See page 68, Biomedical Engineering Option, item 3, for list of approved electives.

B.S. in Electrical Engineering
Computer Engineering Option Curriculum

FRESHMAN YEAR	**UNITS**
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
Computer Science 31 – Introduction to Computer Science I	4
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Computer Science 32 – Introduction to Computer Science II	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Computer Science 33 – Introduction to Computer Organization	5
Mathematics 32A – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
SOPHOMORE YEAR	
1st Quarter	
Electrical Engineering M16 or Computer Science M51A – Logic Design of Digital Systems	4
Mathematics 32B – Calculus of Several Variables	4
HSSEAS GE Electives (2)*	10
2nd Quarter	
Electrical Engineering 1 – Electrical Engineering Physics I	4
Mathematics 33A – Linear Algebra and Applications	4
Physics 4BL – Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	5
3rd Quarter	
Electrical Engineering 2 – Physics for Electrical Engineers	4
Mathematics 33B – Differential Equations	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 10 – Circuit Analysis I	4
Electrical Engineering 101 – Engineering Electromagnetics	4
Electrical Engineering 102 – Systems and Signals	4
Electrical Engineering 103 – Applied Numerical Computing	4
2nd Quarter	
Electrical Engineering 110 – Circuit Analysis II	4
Electrical Engineering M116C or Computer Science M151B – Computer Systems Architecture	4
Electrical Engineering M116L or Computer Science M152A – Introductory Digital Design Laboratory	2
Electrical Engineering 121B – Principles of Semiconductor Device Design	4
Engineering Breadth†	4
3rd Quarter	
Computer Science 111 – Operating Systems Principles	4
Electrical Engineering 110L – Circuit Measurements Laboratory	2
Electrical Engineering 113 – Digital Signal Processing	4
Electrical Engineering 115A – Analog Electronic Circuits I	4
Electrical Engineering M116D or Computer Science M152B – Digital Design Project Laboratory	4
SENIOR YEAR	
1st Quarter	
Electrical Engineering 115AL – Analog Electronics Laboratory I	2
Electrical Engineering 115C – Digital Electronic Circuits	4
Electrical Engineering 131A – Probability	4
HSSEAS GE Elective*	4
Technical Elective‡	4
2nd Quarter	
Computer Science 180 – Introduction to Algorithms and Complexity	4
Mechanical and Aerospace Engineering 182A – Mathematics of Engineering	4
Technical Electives‡	8
3rd Quarter	
Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)	4
HSSEAS GE Elective*	4
Technical Elective‡	4
TOTAL	**190**

*See page 21 for details.
†Course must be selected from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A).
‡See page 68, Computer Engineering Option, item 3, for list of approved electives.

B.S. in Materials Engineering Curriculum

FRESHMAN YEAR	UNITS
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Materials Science and Engineering 10 – Freshman Seminar: New Materials	2
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Computer Science 31 (Introduction to Computer Science I)	4
Mathematics 32A – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
HSSEAS GE Elective*	5
SOPHOMORE YEAR	
1st Quarter	
Materials Science and Engineering 14 – Science of Engineering Materials	4
Mathematics 32B – Calculus of Several Variables	4
Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)	4 or 5
2nd Quarter	
Mathematics 33A – Linear Algebra and Applications	4
Mechanical and Aerospace Engineering M105A – Introduction to Engineering Thermodynamics	4
HSSEAS GE Elective*	4
HSSEAS GE Elective*	5
3rd Quarter	
Materials Science and Engineering 90L – Physical Measurement in Materials Engineering	2
Mathematics 33B – Differential Equations	4
Mechanical and Aerospace Engineering 102 – Mechanics of Particles and Rigid Bodies	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids	4
Electrical Engineering 100 – Electrical and Electronic Circuits	4
Materials Science and Engineering 110/110L – Introduction to Materials Characterization A/Laboratory	6
Materials Science and Engineering 130 – Phase Relations in Solids	4
2nd Quarter	
Materials Science and Engineering 120 – Physics of Materials	4
Materials Science and Engineering 131/131L – Diffusion and Diffusion-Controlled Reactions/Laboratory	6
Materials Science and Engineering 143A – Mechanical Behavior of Materials	4
3rd Quarter	
Materials Science and Engineering 132 – Structure and Properties of Metallic Alloys	4
Materials Engineering Electives (2)	8
Elective†	4
SENIOR YEAR	
1st Quarter	
Materials Science and Engineering 160 – Introduction to Ceramics and Glasses	4
Materials Engineering Elective	4
Upper Division Mathematics Elective	4
2nd Quarter	
Materials Science and Engineering 141L – Computer Methods and Instrumentation in Materials Science	2
Materials Science and Engineering 150 – Introduction to Polymers	4
Elective†	4
HSSEAS GE Elective*	5
3rd Quarter	
Materials Science and Engineering 140 – Materials Selection and Engineering Design	4
Materials Science and Engineering 161L – Laboratory in Ceramics	2
Elective†	4
HSSEAS GE Elective*	4
TOTAL	**182 or 183**

*See page 21 for details.
†See page 84, B.S. in Materials Engineering, item 4, for list of approved electives.

B.S. in Materials Engineering
Electronic Materials Option Curriculum

FRESHMAN YEAR	**UNITS**
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
Computer Science 31 – Introduction to Computer Science I	4
Materials Science and Engineering 10 – Freshman Seminar: New Materials	2
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 32A – Calculus of Several Variables	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
HSSEAS GE Elective*	4
SOPHOMORE YEAR	
1st Quarter	
Materials Science and Engineering 14 – Science of Engineering Materials	4
Mathematics 32B – Calculus of Several Variables	4
HSSEAS GE Elective*	5
2nd Quarter	
Mathematics 33A – Linear Algebra and Applications	4
Mechanical and Aerospace Engineering M105A – Introduction to Engineering Thermodynamics	4
Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)	4 or 5
HSSEAS GE Elective*	5
3rd Quarter	
Materials Science and Engineering 90L – Physical Measurement in Materials Engineering	2
Mathematics 33B – Differential Equations	4
Mechanical and Aerospace Engineering 102 – Mechanics of Particles and Rigid Bodies	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 10 – Circuit Analysis I	4
Electrical Engineering 123A – Fundamentals of Solid-State I	4
Materials Science and Engineering 110/110L – Introduction to Materials Characterization A/Laboratory	6
Materials Science and Engineering 130 – Phase Relations in Solids	4
2nd Quarter	
Electrical Engineering 2 (Physics for Electrical Engineers) or Materials Science and Engineering 120 (Physics of Materials)	4
Electrical Engineering 101 – Engineering Electromagnetics	4
Electrical Engineering 123B – Fundamentals of Solid-State II	4
Materials Science and Engineering 122 – Principles of Electronic Materials Processing	4
3rd Quarter	
Electrical Engineering 121B – Principles of Semiconductor Device Design	4
Materials Science and Engineering 121 – Materials Science of Semiconductors	4
Electronic Materials Laboratory Elective	2
Electronic Materials Major Field Elective†	4
HSSEAS GE Elective*	4
SENIOR YEAR	
1st Quarter	
Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids	4
Electronic Materials Major Field Elective†	4
HSSEAS GE Elective*	5
Upper Division Mathematics Elective	4
2nd Quarter	
Electrical Engineering 122L – Semiconductor Devices Laboratory	4
Materials Science and Engineering 131/131L – Diffusion and Diffusion-Controlled Reactions/Laboratory	6
Electronic Materials Technical Electives (2)	8
3rd Quarter	
Materials Science and Engineering 140 – Materials Selection and Engineering Design	4
Electronic Materials Laboratory Elective	2
Electronic Materials Technical Electives (2)	8
TOTAL	**194 or 195**

*See page 21 for details.
†Select two courses from Materials Science and Engineering 132, 150, 160.

B.S. in Mechanical Engineering Curriculum

Course	Units
FRESHMAN YEAR	**UNITS**
1st Quarter	
Chemistry and Biochemistry 20A – Chemical Structure	4
English Composition 3 – English Composition, Rhetoric, and Language	5
Mathematics 31A – Differential Calculus	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B – Integration and Infinite Series	4
Physics 1A – Mechanics	5
3rd Quarter	
Mathematics 32A – Calculus of Several Variables	4
Mechanical and Aerospace Engineering 20 – Programming with Numerical Methods Applications	4
Physics 1B – Oscillations, Waves, Electric and Magnetic Fields	5
Physics 4AL – Mechanics Laboratory	2
SOPHOMORE YEAR	
1st Quarter	
Mathematics 32B – Calculus of Several Variables	4
Mechanical and Aerospace Engineering 94 – Introduction to Computer-Aided Design and Drafting	4
Physics 1C – Electrodynamics, Optics, and Special Relativity	5
Physics 4BL – Electricity and Magnetism Laboratory	2
2nd Quarter	
Materials Science and Engineering 14 – Science of Engineering Materials	4
Mathematics 33A – Linear Algebra and Applications	4
Mechanical and Aerospace Engineering M105A – Introduction to Engineering Thermodynamics	4
HSSEAS GE Elective*	5
3rd Quarter	
Mathematics 33B – Differential Equations	4
Mechanical and Aerospace Engineering 101 – Statics and Strength of Materials	4
Mechanical and Aerospace Engineering 103 – Elementary Fluid Mechanics	4
HSSEAS GE Elective*	5
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 100 – Electrical and Electronic Circuits	4
Mechanical and Aerospace Engineering 102 – Mechanics of Particles and Rigid Bodies	4
Mechanical and Aerospace Engineering 105D – Transport Phenomena	4
Mechanical and Aerospace Engineering 182A – Mathematics of Engineering	4
2nd Quarter	
Mechanical and Aerospace Engineering 107/107L – Introduction to Modeling and Analysis of Dynamic Systems/Laboratory	4
Mechanical and Aerospace Engineering 131A – Intermediate Heat Transfer	4
Mechanical and Aerospace Engineering 157 – Basic Mechanical Engineering Laboratory	4
HSSEAS GE Elective*	4
3rd Quarter	
Electrical Engineering 110L – Circuit Measurements Laboratory	2
Mechanical and Aerospace Engineering 156A – Strength of Materials	4
Mechanical and Aerospace Engineering 171A – Introduction to Feedback and Control Systems	4
Mechanical and Aerospace Engineering 183 – Introduction to Manufacturing Processes	4
HSSEAS GE Elective*	5
SENIOR YEAR	
1st Quarter	
Mechanical and Aerospace Engineering 133A – Engineering Thermodynamics	4
Mechanical and Aerospace Engineering 162A – Introduction to Mechanisms and Mechanical Systems	4
HSSEAS GE Elective*	4
Mechanical Engineering Elective	4
2nd Quarter	
Mechanical and Aerospace Engineering 162B – Mechanical Product Design	4
Mechanical Engineering Electives (2)	8
Mechanical Engineering Free Technical Elective	4
3rd Quarter	
Mechanical and Aerospace Engineering 162M – Senior Mechanical Engineering Design	4
HSSEAS GE Elective*	5
Mechanical Engineering Electives (2)	8
TOTAL	**193**

*See page 21 for details.

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Financial Aid Office, A129J Murphy Hall
http://www.fao.ucla.edu

Graduate Admissions Office, 1255 Murphy Hall
http://www.gdnet.ucla.edu

International Students and Scholars, Office of, 106 Bradley Hall
http://www.intl.ucla.edu

Housing: Community Housing Office, 360 De Neve Drive
http://www.cho.ucla.edu
UCLA Housing Assignment Office, 360 De Neve Drive
http://www.housing.ucla.edu/myhousing/

Office of the President, Admissions
http://www.universityofcalifornia.edu/admissions/welcome.html

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

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

Undergraduate Admissions and Relations with Schools, 1147 Murphy Hall
http://www.admissions.ucla.edu

Henry Samueli School of Engineering and Applied Science
http://www.engineer.ucla.edu

Office of Academic and Student Affairs, 6426 Boelter Hall
http://www.seasoasa.ucla.edu

Bioengineering Department, 7523 Boelter Hall
http://www.bioeng.ucla.edu

Biomedical Engineering Interdepartmental Program, 7523 Boelter Hall
http://www.bme.ucla.edu

Chemical and Biomolecular Engineering Department, 5531 Boelter Hall
http://www.chemeng.ucla.edu

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

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

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

Materials Science and Engineering Department, 6532 Boelter Hall
http://www.seas.ucla.edu/ms/

Mechanical and Aerospace Engineering Department, 48-121 Engineering IV
http://www.mae.ucla.edu

Continuing Education in Engineering, 542 UNEX
http://www.uclaextension.edu

Engineering and Science Career Services, UCLA Career Center, 501 Westwood Plaza, Strathmore Building
http://career.ucla.edu

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