UCLA

HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE 2002-03

ANNOUNCEMENT
SEPTEMBER 27, 2002

UNIVERSITY OF CALIFORNIA,
LOS ANGELES

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Contents

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All announcements herein are subject to revision. Every effort has been made to ensure the accuracy of the information presented in the *Announcement of the UCLA Henry Samueli School of Engineering and Applied Science.* However, all courses, course descriptions, instructor designations, curricular degree requirements, and fees described herein are subject to change or deletion without notice. Further details on graduate programs are available in various Graduate Division publications which are available online at http://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 the 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 the 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 the Federal and State Laws and University Policies may be maintained in a variety of offices, including the Registrar’s Office, Office of the Dean of Students, UCLA Career Center, Graduate Division, and the offices of a student’s College or school and major department. Students are referred to the *UCLA Telephone Directory* 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 the 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.

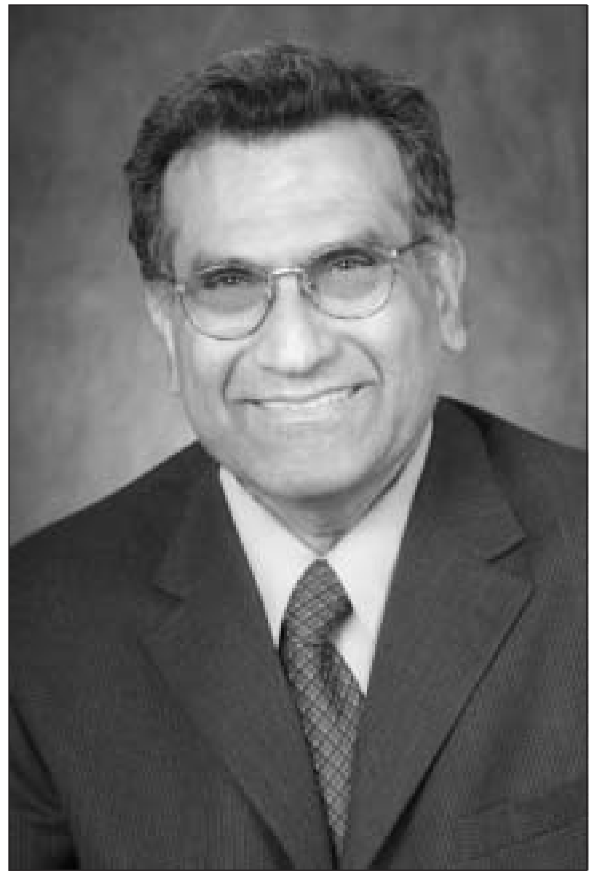
Academic Calendar

	Fall 2002	Winter 2003	Spring 2003
First day for continuing students to check URSA at http://www.ursa.ucla.edu/ for assigned enrollment appointments	June 5, 2002	November 6, 2002	February 12
URSA enrollment appointments begin	June 19	November 18	February 24
Late registration fee payment in person with $50 late fee	September 23-October 11	December 23-January 10	March 21-April 11
QUARTER BEGINS	September 23	January 2	March 26
Instruction begins	September 26	January 6	March 31
Last day for undergraduates to ADD courses with PTE number with $3 per course fee through URSA	October 18	January 24	April 18
Last day for undergraduates to DROP nonimpacted courses (without transcript notation) with $3 per transaction fee through URSA	October 25	January 31	April 25
Last day for undergraduates to change grading basis (optional P/NP) with $3 per transaction fee through URSA	November 8	February 14	May 9
Instruction ends	December 6	March 14	June 6
Final examination week	December 9-13	March 17-21	June 9-13
QUARTER ENDS	December 13	March 21	June 13
HSSEAS Commencement	—	—	June 14
Academic and administrative holidays	November 11 November 28-29 December 24-25 December 31-January 1	January 20 February 17 March 24	May 26 July 4 September 1

Admission Calendar

	Fall 2002	Winter 2003	Spring 2003
Filing period for undergraduate applications (file with UC Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)	November 1-30, 2001	—	October 1-31, 2002
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 12	November 8	February 14
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 25

A Message from the Dean



The Henry Samueli School of Engineering and Applied Science has educated thousands of students and contributed much to this nation's pursuit of knowledge and technology since it was established in 1945 as the UCLA College of Engineering. As an education and research institute, we base our efforts on the premise that excellence in learning, scholarship, and discovery can only be achieved through focus and a determination to be recognized among the very best.

The school is pursuing a versatile program of teaching and research that addresses both our national security requirements and U.S. worldwide competitive commercial needs.

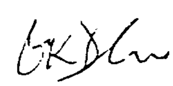
Our reputation is based on active support of teaching and research in new frontiers of applied science and technology, as well as our preeminence in computer networking, micromachines, renewing national infrastructures, protecting our environment and natural resources, wireless communications and computing, optoelectronics, nanoelectronics, smart structures and new materials, signal processing, parallel computing, configurable computing, distributed microsystem networks, sensor technologies, automated flight, semiconductor manufacturing, biotechnology, and biomedical engineering.

In recent years we have embarked on bold new projects. UCLA and UCSB have joined to build the California Nanosystems Institute (CNSI), which facilitates a multidisciplinary approach to develop the information, biomedical, and manufacturing technologies that will dominate science and the economy in the twenty-first century.

Faculty members from four departments — Computer Science, Electrical Engineering, Mechanical and Aerospace Engineering, and Civil and Environmental Engineering — are part of an exciting new research initiative that uses the latest advances in miniaturization, robotics, and Internet technology. The Center for Embedded Networked Sensing brings together numerous disciplines, from engineering to earth sciences to education, in a 10-year research endeavor to develop densely distributed sensors and actuators that can be used to observe, and even alter, natural and man-made environments from complex ecosystems to buildings in earthquake-prone areas.

Other exciting ventures include a project based on a Multimedia Intelligent Network of Unattended Mobile Agents (Minuteman). This portable airborne network system will provide local communications for the military's increasing array of unmanned air and ground vehicles. In addition, UCLA engineers have recently completed a test program in concert with NASA researchers that explored the feasibility of achieving greater fuel efficiency by flying aircraft in formation. Continuing work on navigation and control software and even autonomous flight systems will help make military and commercial air travel safter and more cost efficient. We encourage our undergraduate students to participate in ongoing research endeavors such as these while completing their degree obligations.

Our objective at the Henry Samueli School of Engineering and Applied Science is to recruit outstanding students and distinguished faculty, have excellent research and teaching facilities, and offer quality educational programs at the undergraduate and graduate levels. Our students have gone on to become the chief innovators and leaders in California and throughout the nation and the world. We are seeking exceptional and dedicated students who want to join us in contributing to the community, to science, and to industry. I invite you to consider becoming a UCLA engineer.



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

Henry Samueli School of Engineering and Applied Science

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The Campus

A large urban university, UCLA lies 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. The development of the westside, typified in the high-rise corridors of Wilshire, the transformation of a movie backlot into Century City, and the metamorphosis of Westwood Village from a quaint shopping corner to a metropolitan center, has accompanied the physical expansion and intellectual ferment of UCLA.

UCLA is devoted to scholarship, research, and public service. Some 291 buildings on 419 acres house the College of Letters and Science plus 11 professional schools and serve over 37,490 students. 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. It is a place for serious study in a vibrant, dynamic atmosphere.

The history of UCLA parallels the emergence of the coastal Southwest as one of the nation's dominant industrial centers, and the Henry Samueli School of Engineering and Applied Science (HSSEAS) is the hub of engineering research and professional training for this vast region. As such, the school is poised to be a preeminent center of research benefiting the entire nation.

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 83-year history.

The School

Opened as the College of Engineering in 1945, HSSEAS now ranks among the top 10 engineering schools in public universities nationwide. The school houses several research centers, including the Nanoelectronics Research Facility, Center for Embedded Networked Sensing, Center for High-Frequency Electronics, Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Facilities, and Active Materials Laboratory. Current research programs focus on such areas as the twenty-first century internet, microelectromechanical (MEMS) devices, wireless electronics, "smart" materials, earthquake engineering, neuroengineering, metabolic engineering, and environmental cleanup and waste management.

The school's seven departments — Bioengineering, Chemical Engineering, Civil and Environmental Engineering, Computer Science, Electrical Engineering, Materials Science and Engineering, and Mechanical and Aerospace Engineering — offer instruction and research in the traditional specialities of the engineering profession to undergraduate and graduate students. In addition, the Biomedical Engineering interdepartmental program is engaged in graduate training and research. Each department has its own faculty, set of courses, fields of specialization, and curriculum requirements. Some offer more than one undergraduate curriculum.

HSSEAS offers 27 academic and professional degree programs, including an interdepartmental graduate degree program in biomedical engineering. The Bachelor of Science degree is offered in Aerospace Engineering, 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 firm 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, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Manufacturing Engineering (M.S. only), Materials Science and Engineering, and Mechanical Engineering. The Master of Engineering degree may be earned through the Engineering Executive Program. 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.

The Biomedical Engineering Interdepartmental Graduate Program trains students for M.S. and Ph.D. degrees in Biomedical Engineering. Students can specialize in courses and research in the following fields: biomedical signal and image processing and bioinformatics; bioacoustics, speech, and hearing; biomedical instrumentation; biomechanics, biomaterials, and tissue engineering; molecular and cellular bioengineering; biocybernetics; and neuroengineering.

Endowed Chairs

Endowed professorships or chairs, funded by private gifts, support the educational and research activities of distinguished members of the faculty. The following are the chairs established in HSSEAS.

L.M.K. Boelter Chair in Engineering

Roy and Carol Doumani Chair in Biomedical Engineering

Norman E. Friedmann Chair in Knowledge Sciences

Hughes Aircraft Company Chair in Electrical Engineering

Hughes Aircraft Company Chair in Manufacturing Engineering

Levi James Knight, Jr., Chair in Engineering

Nippon Sheet Glass Company Chair in Materials Science

Northrop Chair in Electrical Engineering/ Electromagnetics

Ralph M. Parsons Chair in Chemical Engineering

Ben Rich Lockheed Martin Chair in Aeronautics

Rockwell International Chair in Engineering

William Frederick Seyer Term Chair in Materials Electrochemistry

TRW Chair in Electrical Engineering

The Engineering Profession

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

Aerospace Engineering

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

Working in a high-technology industry, aerospace engineers are generally well versed in applied mathematics and the fundamental engineering sciences, particularly fluid mechanics and thermodynamics, dynamics and control, and structural and solid mechanics. Aerospace vehicles are complex systems. Proper design and construction involves the coordinated application of technical disciplines, including aerodynamics, structural analysis and design, stability and control, aeroelasticity, performance analysis, and propulsion 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 21st century, bioengineers solve problems in biology and medicine by applying principles of physical sciences and engineering and 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 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. 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 tissue 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. Someone with an emphasis in bioinformatics may begin a career by data mining the human proteome at NIH before advancing to academia to develop data structure for DNA computing.

Chemical Engineering

Chemical engineers use their knowledge of mathematics, physics, and chemistry 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, and control, which provides 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, 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 69. 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 HSSEASnet 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 Water Resources Center Archives, 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 7.5 million volumes, and more than 93,000 serial titles are received regularly.

Science and Engineering Library

Collections and services of the Science and Engineering Library (SEL) support research and programs in all HSSEAS departments and in Atmospheric Sciences, Chemistry and Biochemistry, Earth and Space Sciences, Mathematics, Physics and Astronomy, Statistics, and related institutes. The main SEL site houses the engineering, mathematics, astronomy, and atmospheric sciences collections, most public service staff and librarians, and divisions for administration, cataloguing, collection development, public services, and interlibrary loan. Chemistry, geology-geophysics, and physics collections are in separate buildings.

The SEL collection contains over 559,000 volumes, subscriptions to almost 7,000 current serials, and over 4,000,000 technical reports. Online and in-person reference assistance is provided weekdays. Faculty, staff, and students can e-mail questions to the library at sel-ref@library.ucla.edu.

The library provides access to both virtual and real resources, including e-journals, e-books, and article and journal databases, in addition to appropriate print equivalents. Materials can be renewed by using “My Account” on ORION2 (online catalog). Copy machines and microform readers/printers are available. Reserve and interlibrary loan of material, as well as other services, are available via the SEL Website. See http://www.library. ucla.edu/libraries/sel/.

Services

Instructional Computer Facility

HSSEAS maintains a UNIX network of eight IBM AIX RISC System/6000 computers, 25 Sun Solaris computers, four Sun Enterprise 220/280 servers, and two Network Appliance 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. Five open computer laboratories and one classroom for computerized instruction house 180 of the PC workstations.

In addition, UCLA Academic Technology Services (ATS) operates a 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 128 annual offerings draws participants from around the world for two- to five-day intensive programs. The acclaimed Technical Management Program holds its sixty-fourth offering in September 2002 and sixty-fifth in March 2003. The Information Systems program — offering 600 classes annually, including six certificated programs and four sequential programs in evening, day, and weekend formats — covers a broad range of information technologies.

The department is a member of the Microsoft IT Academy Program and the Oracle Workforce Development Program, and an Authorized Sun Education Center and offers a Cisco certified curriculum. Each year, the department offers 40 classes in an online format, plus 200 classes in engineering disciplines that include manufacturing, electrical engineering, astronautical engineering, construction, technical management, and PE review classes. Most engineering 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) 825-0328 or (310) 206-1548 for engineering or technical management classes, or fax (310) 206-2815. See http://www.uclaextension.org.

Career Services

Engineering and Science Career Services

Engineering and Science Career Services (5289 Boelter Hall), 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. Bruintraks™, available on the Career Center website, 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.

Engineering and Science Career Services also provides consultation services to HSSEAS student organizations.

Engineering and Science Career Services is open from 9 a.m. to 5 p.m. Monday through Friday, with extended evening hours until 7 p.m. on Tuesdays. For more information, call (310) 825-4606 or see http://www.career.ucla.edu/students/escpo.htm.

Ashe Student Health and Wellness Center

The Ashe Student Health and Wellness Center, 221 Westwood Plaza (310-825-4073; http://www.studenthealth.ucla.edu), is an outpatient clinic for UCLA students. Most services are prepaid by registration fees, and a current BruinCard is required for service. Core (prepaid) services include visits, most procedures, X rays, and some laboratory procedures. Noncore (fee) services, such as pharmaceuticals, injections, orthopedic devices, and some laboratory procedures, are less costly than elsewhere. If students withdraw during a school term, all Ashe Center services continue to be available on a fee basis for the remainder of that term, effective from the date of withdrawal.

All UCLA undergraduate students are automatically assessed for and enrolled in the Undergraduate Student Health Insurance Plan (USHIP) as a condition of registration at UCLA. Continued enrollment in adequate medical/health insurance must be maintained during all registered terms.

All UCLA graduate students are automatically assessed for and enrolled in the Graduate Student Health Insurance Plan (GSHIP) as a condition of registration at UCLA. Continued enrollment in adequate medical/health insurance must be maintained during all registered terms.

The USHIP and GSHIP fees are billed each term along with other UCLA fees. USHIP/GSHIP fulfills all of the requirements mandated for adequate medical/health insurance as defined by the University. The Ashe Student Health and Wellness Center is the primary health care provider for USHIP/GSHIP and is where all nonemergency medical care must be initiated for USHIP/GSHIP claim payment consideration. See http://www.studenthealth.ucla.edu.

Services for Students with Disabilities

The Office for Students with Disabilities (OSD), A255 Murphy Hall (voice 310-825-1501, TDD 310-206-6083, fax 310-825-9656, http://www.saonet.ucla.edu/osd/), provides 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 of 1990, and University policies. Academic support services are determined for each student based on specific disability-based requirements. Services include readers, note takers, sign language interpreters, Learning Disabilities Program, special parking, registration assistance, fee deferments authorized by the California Department of Rehabilitation, on-campus transportation, campus orientation and accessibility, proctor and test-taking arrangements, tutorial referral, housing assistance, support groups, workshops, special materials, adaptive equipment, and referral to the Disabilities and Computing Program. There is no fee for any of these services, and all contacts and assistance are handled confidentially.

Fees and Financial Support

Fees and Expenses

The 2003-03 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.

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, 350 De Neve Drive (Sproul Hall Annex),

2002-03 Annual UCLA Graduate and Undergraduate Fees

Fees are subject to revision without notice

	Graduate Students		Undergraduate Students	
	Resident	Nonresident	Resident	Nonresident
University registration fee	$ 713.00	$ 713.00	$ 713.00	$ 713.00
Educational fee	2,896.00	3,086.00	2,716.00	3,086.00
Undergraduate Students Association fee			72.27	72.27
Graduate Students Association fee	30.00	30.00		
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
Mandatory medical insurance	750.00	750.00	564.00	564.00
Nonresident tuition		11,132.00		12,009.00
Total mandatory fees	$ 4,548.50	$15,870.50	$ 4,224.77	$16,603.77

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

The Dashew International Student Center, 106 Bradley Hall, (310) 825-1681, 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 2003-04 academic year is March 2, 2003. 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; 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

Andersen Consulting Outstanding Junior Award in memory of Kalpesh Vardhan. For an outstanding junior engineering student; one-year $2,000 award

ARCO Products Company Scholarship. For students in chemical engineering

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

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

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

Fluor Daniel Scholarship. For a junior chemical, civil, electrical (control systems), or mechanical engineering major; two-year award

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

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

Intel Scholarship. For computer science, computer science and engineering, and electrical engineering students; renewable scholarships

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

Litton Industries Scholarship/Award. For a student in electrical, mechanical, or computer 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 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.

Information on loan repayment is available from the Student Loan Services Office, A227 Murphy Hall.

Before graduating, transferring, or withdrawing from UCLA, students who have received loans from the Financial Aid Office must schedule an exit interview with the Student Loan Services Office to discuss terms and conditions of their loan. For an appointment, call (310) 825-9864. Failure to have an interview results in a hold on student academic records.

Additionally, if loans become delinquent following separation from the University, University services, including academic records, are withheld.

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 full-time (12 units for undergraduates, 8 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

About half 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 (215 positions).
2. Employment as a teaching assistant (about 416 positions).
3. Employment as a graduate student researcher (about 662 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 $14,145* to $16,584*, 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 $15,762† to $20,142†, 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.

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2003-04 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.

*Nine-month 2001-02 salaries
†Eleven-month 2001-02 salaries

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 November 2002 for information on 2003-04 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. Supports entering graduate students in the area of hazardous substance control; administered by the UCLA Center for Clean Technology

William and Mary Beedle Fellowship. Department of Chemical 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

National Science Foundation Fellowship. Department of Chemical Engineering, Supports study in chemical engineering

Rand Corporation/UCLA Fellowship. Supports study in all fields of engineering and applied science, artificial intelligence, and hazardous substance control; must be U.S. citizen; includes summer employment at Rand

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

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

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

School of Engineering and Applied Science (SEAS) Industrial Associates Fellowships. Supports study in all fields of engineering

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

U.S. Department of Education Fellowship in Pollution Prevention. Department of Chemical Engineering; supports study in pollution prevention

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 1,200 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 16 schools in the Los Angeles Unified School District and eight schools in the Inglewood Unified School District.

Hewlett-Packard Diversity in Education Initiative (HP-DEI). Funded by the Hewlett-Packard Foundation, HP-DEI is a collaboration between CEED and Los Angeles Unified School District-Los Angeles Systemic Initiative to implement

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

mathematics/science reform in 12 urban schools. One component of HP-DEI is the **Academic Boot Camp**, which supports 170 students in grades four to eight from HP partner schools in a five-week summer mathematics and science enrichment camp. Seven Saturday Academies are offered during the school year as follow-up. A second component is the **Teacher Training Program**, an inquiry-centered curricula and collaborative learning pedagogy developed by the Los Angeles Systemic Initiative and the National Science Resource Center.

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 97-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.

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.

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.

A key component of OMEGA is recruitment. OMEGA maintains communication with a network of 15 student organizations from which to identify and cultivate prospective graduate students.

The OMEGA Faculty/Student social pairs engineering juniors and seniors with UCLA engineering faculty by subfield specialties over dinner. The faculty can thus assist UCLA and non-UCLA students in planning for graduate school and help them gain an understanding of the research enterprise.

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 twelfth 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 21 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/students/organ.htm.

EGSA	Engineering Graduate Students Association
ESUC	Engineering Society, University of California. Undergraduate organization that provides a focus for many student activities: sponsors Engineers Week each year and maintains the ESUC lounge in 5800E Boelter Hall
AES	Audio Engineering Society
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
Eta Kappa Nu	Electrical engineering honor society
IEEE	Institute of Electrical and Electronic Engineers
NSBE	National Society of Black Engineers
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 professional engineering fraternity
Upsilon Pi Epsilon	Computer Science Honor Society

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.

Outstanding B.S., M.S., and Ph.D. awards are given to those degree candidates who have achieved academic excellence. Criteria may include such items as grade-point average, creativity, research, and community service.

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.

Departmental Scholar Program

The school may nominate exceptionally promising junior and senior undergraduate students 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.

Interested students should consult the associate dean in 6412 Boelter Hall well in advance of application dates for admission to graduate standing.

Engineering and Applied Science Cooperative Education Program

The Cooperative Education Program is a plan wherein undergraduate students combine periods of regular employment in private industry or government activities (federal, state, county, or city) with alternate periods of study. The work experience becomes a regular, continuing, and essential part of their professional education.

This elective plan involves no academic credit for work periods, but students in work periods are encouraged to take such courses as they may be able to arrange, particularly in the Continuing Education Program.

Further information and applications may be obtained at the Engineering and Science Career Planning Office, 5289 Boelter Hall.

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.

Rules and regulations on graduate study at UCLA are at 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, 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 Douglas A. Martin, Special Assistant to the Chancellor/Coordinator of ADA and 504 Compliance, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 825-2242, 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/uwnews/aospol/toc.html) for further information and procedures.

Harassment

Sexual Harassment

Every member of the campus community should be aware that the University is strongly opposed to sexual harassment and that such behavior is prohibited both by law and by University policy.

Definitions

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

1. Submission to such conduct is made either explicitly or implicitly a term or condition of instruction, employment, or participation in other University activity;
2. Submission to or rejection of such conduct by an individual is used as a basis for evaluation in making academic or personnel decisions affecting an individual; or
3. Such conduct has the purpose or effect of unreasonably interfering with an individual's performance or creating an intimidating, hostile, or offensive University environment.

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 context in which the alleged incidents occurred (*University of California Policies Applying to Campus Activities, Organizations, and Students,* Section 160.00).

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. Academic Personnel, Assistant to the Vice Chancellor — Academic Personnel, 3109 Murphy Hall, (310) 794-4217
2. Office of Ombuds Services, 105 Strathmore Building, (310) 825-7627
3. Center for Student Programming, Associate Director, 105 Kerckhoff Hall, (310) 825-7041
4. Center for Women and Men, Director, 2 Dodd Hall, (310) 825-3945
5. Office of the Dean of Students, Assistant Dean of Students, 1206 Murphy Hall, (310) 825-3871
6. Campus Human Resources/Employee and Labor Relations, Manager, 200 UCLA Wilshire Center, (310) 794-0860
7. Graduate Division, Office Manager, 1237 Murphy Hall, (310) 825-4383

8. Healthcare Human Resources, Employee Relations Manager, 924 Westwood Boulevard, Suite 200, (310) 794-0500
9. Neuropsychiatric Hospital, Administration/Human Resources Associate Director, B7-370 NPI&H, (310) 206-5258
10. Office of Residential Life, Judicial Coordinator, Residential Life Building, (310) 825-3401
11. School of Dentistry, Assistant Dean, Student and Alumni Affairs, A3-042 Dentistry, (310) 825-7146; Student and Alumni Affairs Counselor, 23-087 Dentistry, (310) 8250-5248
12. School of Medicine, Human Resources Director, 924 Westwood Boulevard, Suite 540, (310) 794-6802; 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
13. Staff Affirmative Action Office, Staff Affirmative Action Officer, 1103 Ueberroth Building, (310) 825-0751
14. Student Psychological Services, Director, 4223 Math Sciences, (310) 825-0768
15. UCLA Extension, Human Resources Director, 629 UNEX Building, (310) 825-4287; Student Services Director, 214 UNEX Building, (310) 825-2656
16. Santa Monica UCLA Medical Center, Healthcare Human Resources Manager, 1250 16th Street, Santa Monica 90404, (310) 319-4351

Other Forms of Harassment

The University strives to create an environment which 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*) 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, 2 Dodd Hall, (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/home.htm
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, (310) 825-3401, http://www.orl.ucla.edu/
6. Student Psychological Services, 4223 Math Sciences, (310) 825-0768, or A3-062 Center for the Health Sciences, (310) 825-7985, http://www.saonet.ucla.edu/sps.htm

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

Admission

Applicants to HSSEAS must satisfy the general admission requirements of the University. See the *UCLA General Catalog* (http://www.registrar.ucla.edu/catalog) 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 for the Scholastic Assessment Test (SAT) I — or American College Test (ACT) — and three SAT II: Subject Tests be received no later than the date in January when the December test scores are normally reported.

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

It is anticipated that admission to the school will require that the following subjects be taken when satisfying the University admission requirements:

Algebra	2 years
Plane geometry	1 year
Trigonometry	.5 year
Chemistry and physics with laboratory	2 years

Freshman applicants must meet the University subject, scholarship, and examination requirements described in the *UCLA General Catalog.*

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 5, 4, or 3. 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 2002 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

To be considered for admission to HSSEAS and to be considered a junior in the engineering majors, applicants must satisfy the general admission requirements of the University (see the *UCLA General Catalog*) and in addition should have followed an engineering or pre-engineering program at

LOWER DIVISION PREPARATION FOR THE MAJORS

	UCLA Equivalent Courses
Mathematics	
Analytic geometry and calculus, 8 units; calculus of several variables, 8 units; matrices and differential equations, 4 units; infinite series, 4 units (total of 24 quarter units minimum)	Mathematics 31A, 31B Mathematics 32A, 32B Mathematics 33A, 33B
Physics	
Calculus-based courses in mechanics of solids, vibration, wave motion, sound, fluids, heat, kinetic theory, electricity, magnetism, electromagnetic waves, light and relativity, with laboratory (total of 19 quarter units minimum)	Physics 1A*, 1B*, 1C*, 4AL*, 4BL*
Chemistry†	
Two quarters or two semesters of general chemistry with laboratory (total of 11 quarter units minimum)	Chemistry and Biochemistry 20A, 20B, 20L‡
Engineering	
Digital computer programming, using a higher-level language such as FORTRAN, PASCAL, C, or C++ (4 units); other courses: statics, dynamics, graphics and descriptive geometry, surveying, circuit analysis, properties of materials, strength of materials, additional chemistry, additional computer science	Civil and Environmental Engineering 15; Computer Science 31; Mechanical and Aerospace Engineering 20; engineering core** courses; free electives**
Additional Courses	HSSEAS general education

*Depending on curriculum selected.
†Only Chemistry and Biochemistry 20A is required for the Computer Science and Engineering degree; chemistry is not required for the Computer Science degree.
‡ Chemical Engineering curriculum also requires Chemistry and Biochemistry 30A, 30AL, 30B, 30BL.
**See specific undergraduate curricula listed at the end of this announcement for core courses, HSSEAS general education (GE) courses, and free electives, depending on curriculum followed.

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., Life Sciences 15), 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 unassigned units	No application
Art, Studio		*8 units maximum for all tests*	
Two-Dimensional Design Portfolio	3, 4, or 5	8 unassigned units	No application
Three-Dimensional Design Portfolio	3, 4, or 5	8 unassigned units	No application
General Portfolio (no longer offered)	3, 4, or 5	8 unassigned units	No application
Biology	3, 4, or 5	4 GE units plus 4 unassigned units	4 units toward life sciences requirement
Chemistry	3, 4, or 5	8 units (credit determined on an individual basis)	No application
Computer Science		*4 units maximum for both tests*	
Computer Science (A Test)	3, 4, or 5	2 unassigned units	No application
Computer Science (AB Test)	3	Credit determined on an individual basis	No application
	4 or 5	Computer Science 31 (4 units)	No application
Economics			
Macroeconomics	3	4 unassigned units	No application
	4 or 5	Economics 2 (4 units)	4 units toward social sciences requirement
Microeconomics	3	4 unassigned units	No application
	4 or 5	Economics 1 (4 units)	4 units toward social sciences requirement
English		*8 units maximum for both tests*	
Language and Composition	3	8 unassigned units	Satisfies Subject A requirement
	4 or 5	English Composition 3 (5 units) plus 3 unassigned units	Satisfies Subject A requirement
Literature and Composition	3	8 unassigned units	Satisfies Subject A requirement
	4 or 5	English Composition 3 (5 units) plus 3 unassigned units	Satisfies Subject A requirement
Environmental Science	3	4 unassigned units	No application
	4 or 5	4 GE units	4 units toward life sciences requirement
Geography, Human	3, 4, or 5	4 unassigned units	No application
Government and Politics			
Comparative	3, 4, or 5	4 GE units	4 units toward social sciences requirement
United States	3, 4, or 5	4 GE units	4 units toward social sciences requirement; satisfies American History and Institutions requirement
History			
European	3, 4, or 5	History 1C (4 units) plus 4 unassigned units	4 units toward social sciences requirement
United States	3	8 unassigned units	Satisfies American History and Institutions requirement

	4 or 5	History 13A, 13B, 13C (8 units)	8 units toward social sciences requirement; satisfies American History and Institutions requirement
World	3, 4, or 5	8 unassigned units	No application
Languages and Literatures			
French Language	3	French 4 (4 units) plus 4 unassigned units	4 units toward humanities requirement
	4	French 5 (4 units) plus 4 unassigned units	4 units toward humanities requirement
	5	French 6 (4 units) plus 4 unassigned units	4 units toward humanities requirement
French Literature	3, 4, or 5	8 unassigned units	No application
German Language	3	German 3 (4 units) plus 4 unassigned units	No application
	4	German 4 (4 units) plus 4 unassigned units	4 units toward humanities requirement
	5	German 5 (4 units) plus 4 unassigned units	4 units toward humanities requirement
Latin		*8 units maximum for both tests*	
Latin Literature	3	Latin 1 (4 units)	No application
	4 or 5	Latin 3 (4 units)	No application
Vergil	3	Latin 1 (4 units)	No application
	4 or 5	Latin 3 (4 units)	No application
Spanish Language	3	Spanish 4 (4 units) plus 4 unassigned units	4 units toward humanities requirement
	4	Spanish 5 (4 units) plus 4 unassigned units	4 units toward humanities requirement
	5	Spanish 6 (4 units) plus 4 unassigned units	4 units toward humanities requirement
Spanish Literature	3, 4, or 5	8 unassigned units	No application
Mathematics		*8 units maximum for both tests*	
Mathematics (AB Test: Calculus)	3	4 units	No application
	4 or 5	Mathematics 31A (4 units)	No application
Mathematics (BC Test: Calculus)	3	8 units	No application
	4 or 5	Mathematics 31A, 31B (8 units)	No application
Music		*8 units maximum for both tests*	
Music Literature (no longer offered)	3, 4, or 5	8 unassigned units	No application
Music Theory	3, 4, or 5	8 unassigned units	No application
Physics		*8 units maximum for all tests*	
Physics (B Test)	3, 4, or 5	8 unassigned units	No application
Physics (C Test: Mechanics)	3, 4, or 5	4 units (credit determined on an individual basis)	No application
Physics (C Test: Electricity and Magnetism)	3, 4, or 5	4 units (credit determined on an individual basis)	No application
Psychology	3	4 unassigned units	No application
	4 or 5	Psychology 10 (4 units)	4 units toward social sciences requirement
Statistics	3	4 unassigned units	No application
	4 or 5	Statistics 10 (4 units)	No application

the previous college or university they attended. They should have completed, insofar as possible, courses that apply to HSSEAS requirements (that is, courses that satisfy requirements for the curricula they plan to pursue). All lower division requirements must be completed by the end of the spring term prior to anticipated enrollment at UCLA. General requirements for transfer applicants, as well as articulation agreements for a number of California community colleges, are at http://www.seasoasa.ucla.edu/.

Transfer students who have completed the recommended lower division program in engineering at California community colleges should be able to complete the remaining requirements for one of the B.S. degrees in six terms (two academic years) of normal full-time study. Students who select certain majors, such as Computer Science and Engineering or Chemical Engineering, may be required to complete additional lower division courses as requisites for the major sequence.

Transfer students must complete a course equivalent to UCLA's English Composition 3 and a second more advanced course in English composition.

Students transferring to the school from institutions that offer instruction in engineering subjects in the first two years, particularly California community colleges, are given credit for certain engineering core requirements.

Many sophomore courses in circuit analysis, strength of materials, and properties of materials may satisfy Electrical Engineering 100, Civil and Environmental Engineering 108, and Materials Science and Engineering 14 requirements respectively.

A course in digital computer programming, using a higher-level language such as FORTRAN, PASCAL, C, or C++, satisfies the computer programming requirement. Applicants to majors in Computer Science, Computer Science and Engineering, and Electrical Engineering should take C++.

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, 31B. Calculus and Analytic Geometry (4 units each)
Mathematics 32A, 32B. Calculus of Several Variables (4 units each)
Mathematics 33A. Linear Algebra and Applications (4 units)
Mathematics 33B. Infinite Series and 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.

The curricular requirements for the B.S. degrees in Aerospace Engineering, Chemical Engineering, Civil Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering consist of completing the minimum number of required units (from 180 to 203 units, depending on the curriculum selected), the general University requirements in scholarship, Subject A or English as a Second Language (ESL), and American History and Institutions, and the school requirements for scholarship and senior residence. The curricular requirements are described within each department.

University Requirements

These requirements are discussed in detail in the Undergraduate Study section of the *UCLA General Catalog.*

School Requirements

Scholarship and Minimum Progress

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.

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

Senior Residence

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.

Study Lists and Credit Limitations

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 18 units per term unless an Excess Unit Petition is approved in advance by the dean.

Students must attain a minimum grade of C to satisfy the English Composition 3 requirement, which must be met by the end of the second year of enrollment at UCLA (a grade of C– does not satisfy this requirement). Undergraduates who have not taken (or otherwise satisfied the requirement for) English Composition 3 at the time they are admitted must complete the course at UCLA during Fall, Winter, Spring, or Summer Quarter. Students may also complete the equivalent to English Composition 3 at any other UC campus during the Summer Quarter only.

After 213 quarter units, enrollment may not normally be continued in the school. Students may petition the dean for special permission to continue work required to complete the degree. This regulation does not apply to Departmental Scholars.

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.

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

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.

Curricular Requirements

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

15. Fourteen to 21 engineering major field courses (56 to 84 units), depending on curriculum followed
16. One to 10 engineering core courses (4 to 40 units), depending on curriculum selected
17. Mathematics courses, ranging from 4 to 12 upper division units; see curricula in individual departments
18. HSSEAS general education (GE) requirements: (a) English Composition 3, which must be completed with a minimum grade of C by the end of the second year of enrollment at UCLA; (b) six courses from the humanities and social sciences (eight courses for Computer Science majors), with at least two courses from each category; (c) one life sciences course (two courses for Computer Science majors; this requirement is automatically satisfied for Chemical Engineering majors)

    All lower division courses taken to satisfy items b and c must be selected from the HSSEAS GE course list at http://www.seaoasa.ucla.edu/ge.html. Students interested in taking a foreign language to satisfy this requirement must first consult with an academic counselor in the Office of Academic and Student Affairs, 6426 Boelter Hall.

    For item b, at least three courses must be in the same academic department or must otherwise reflect coherence in subject matter. Of the three, at least two must be upper division courses selected from the approved HSSEAS GE course list.

    Computer Science, Computer Science and Engineering, and Electrical Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 194 or 195, which may be applied toward either the humanities or social sciences section of the GE requirements.

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

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.

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

19. 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.
20. All HSSEAS undergraduates may use the computerized HSSEAS Academic Program Planner, 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.

Passed/Not Passed Grading

Students may take one 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. Only HSSEAS general education courses (with the exception of English Composition 3 and the ethics course) may be taken on a Passed/Not Passed basis. For more details on P/NP grading, see the Academic Policies section in the *UCLA General Catalog* or consult the Office of Academic and Student Affairs.

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 2002-03 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 grade-point average at graduation which places them in the top five percent of the school (GPA of 3.809 or better) for summa cum laude, the next five percent (GPA of 3.699 or better) for magna cum laude, and the next 10 percent (GPA of 3.537 or better) for cum laude.

Based on grades achieved in upper division courses, engineering students must have a 3.809 grade-point average for summa cum laude, a 3.699 for magna cum laude, and a 3.537 for cum laude. For all designations of honors, students must have a minimum 3.25 grade-point average 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 GPA 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 GPA 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
Molecular and cellular bioengineering
Neuroengineering

Chemical Engineering Department

Chemical engineering

Civil and Environmental Engineering Department

Environmental engineering
Geotechnical engineering
Structures (structural mechanics and earthquake engineering)
Water resources engineering

Computer Science Department

Artificial intelligence
Computer networks
Computer science theory
Computer system architecture
Information and data management
Scientific computing (biomedical engineering systems and biocybernetics, physical systems)
Software systems and languages

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
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 and fusion engineering (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, refer to Graduate Admission in the Graduate Study section of the *UCLA General Catalog.*

Obtain admission forms by writing to the department of interest, Henry Samueli School of Engineering and Applied Science, UCLA, Los Angeles, CA 90095. Students may also submit an online application at http://www.engineer.ucla.edu/. From there connect to the preferred department or program and then to the online graduate application.

Graduate Record Examination

Applicants to the graduate engineering programs are required to take the General Test of the Graduate Record Examination (GRE). Applicants for the graduate computer science programs are required to take the GRE General Test and Subject Test in Mathematics or Computer Science. 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/.

Engineering commencement

Departments and Programs of the School

Bioengineering

UCLA
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Assistant Professors

James Dunn, M.D., Ph.D.
Benjamin Wu, D.D.S., Ph.D.

Adjunct Associate Professors

Toshikazu Hamasaki, Ph.D.
Hercules Neves, Ph.D.

Adjunct Assistant Professor

Jacob Schmidt, Ph.D.

Scope and Objectives

The Department of Bioengineering was recently approved, and plans are underway to develop a scholastic program that treats bioengineering as a discrete engineering science discipline. Through intensive training in both modern biology and engineering science, the department provides the educational platform necessary for students to become leaders in the fields that are evolving from the convergence of the biological and physical sciences.

Considerable resources have been allocated to support the establishment of a world-class academic unit, including the construction of unique state-of-the-art laboratory teaching facilities dedicated to instructing students in the most advanced techniques for fabricating hybrid living/nonliving devices. Students enrolled in both the undergraduate and graduate programs learn how to design engineering systems that integrate with living systems of all size scales, starting at the molecular/nanoscale level.

Undergraduate and graduate programs are expected to be in place by Fall Quarter 2003. Transfer and graduate students will be accepted during 2003, while the first freshman class will be admitted for Fall Quarter 2004.

Biomedical Engineering

Interdepartmental Program

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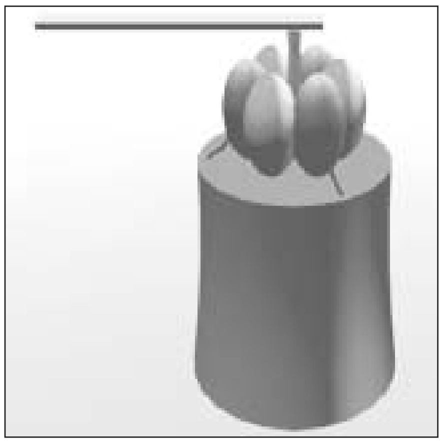

Depiction of hybrid nano device

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

Professors

Abeer A.H. Alwan, Ph.D. *(Electrical Engineering)*
Arthur P. Arnold, Ph.D. *(Neurobiology, Physiological Science)*
Rajive Bagrodia, Ph.D. *(Computer Science)*
Arnold J. Berk, M.D. *(Microbiology, Immunology, and Molecular Genetics)*
Sally Blower, Ph.D. *(Biomathematics)*
Elliott Brown, Ph.D. *(Electrical Engineering)*
Angelo Caputo, Ph.D. *(Dentistry)*
Marie Françoise Chesselet, M.D., Ph.D. *(Neurology)*
Mark Cohen, Ph.D. *(Neurology, Radiological Sciences, Psychiatry and Biobehavioral Sciences)*
Yoram Cohen, Ph.D. *(Chemical Engineering)*
*Jean B. deKernion, M.D. *(Urology)*
Joseph L. Demer, M.D., Ph.D. *(Ophthalmology, Neurology)*
*Linda Demer, M.D., Ph.D. *(Cardiology, Physiology)*
Vijay K. Dhir, Ph.D. *(Mechanical and Aerospace Engineering)*
Joseph J. DiStefano III, Ph.D. *(Computer Science, Medicine)*
Bruce H. Dobkin, M.D. *(Neurology)*
*Bruce S. Dunn, Ph.D. *(Materials Science and Engineering)*
V. Reggie Edgerton, Ph.D. *(Physiological Science)*
Jack L. Feldman, Ph.D. *(Physiological Science, Neurobiology)*
Harold R. Fetterman, Ph.D. *(Electrical Engineering)*
Gerald A.M. Finerman, M.D. *(Orthopaedic Surgery)*
C. Fred Fox, Ph.D. *(Microbiology, Immunology, and Molecular Genetics)*
C.R. Gallistel, Ph.D. *(Psychology)*
Bruce R. Gerratt, Ph.D. *(Head and Neck Surgery)*
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Vijay Gupta, Ph.D. *(Mechanical and Aerospace Engineering)*
*Chih-Ming Ho, Ph.D. *(Mechanical and Aerospace Engineering, Ben Rich Lockheed Martin Professor of Aeronautics, Center for Micro Systems Director)*
Edward J. Hoffman, Ph.D. *(Molecular and Medical Pharmacology, Radiological Sciences)*
Henry S.C. Huang, D.Sc. *(Molecular and Medical Pharmacology, Biomathematics)*
Stephen E. Jacobsen, Ph.D. *(Electrical Engineering)*
Bahram Jalali, Ph.D. *(Electrical Engineering)*
J-Woody Ju, Ph.D. *(Civil and Environmental Engineering)*
J. Michael Kabo, Ph.D. *(Orthopaedic Surgery)*
William J. Kaiser, Ph.D. *(Electrical Engineering)*
Hooshang Kangarloo, M.D. *(Radiological Sciences, Pediatrics)*
Patricia A. Keating, Ph.D. *(Linguistics)*
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 Engineering)*
Jia-Ming Liu, Ph.D. *(Electrical Engineering)*
Ajit K. Mal, Ph.D. *(Mechanical and Aerospace Engineering)*
Keith Markolf, Ph.D. *(Orthopaedic Surgery)*
Istvan Mody, Ph.D. *(Neurology, Physiology)*
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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)*
*Allan J. Tobin, Ph.D. *(Neurology, Physiological Science)*
Arthur Toga, Ph.D. *(Neurology)*
John D. Villasenor, Ph.D. (*Electrical Engineering*)

* Faculty Advisory Committee

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)*

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Gregory Carman, Ph.D. *(Mechanical and Aerospace Engineering)*
Gary Duckwiler, M.D. *(Radiological Sciences)*
Sanjiv Gambhir, Ph.D. *(Molecular and Medical Pharmacology)*
Alan Garfinkel, Ph.D. *(Physiological Science, Cardiology)*
Robin L. Garrell, Ph.D. *(Chemistry and Biochemistry)*
Marc Hedrick, M.D. *(Surgery)*

Assistant Professors

Marvin Bergsneider, M.D. *(Neurosurgery)*
Ramin Beygui, M.D. *(Surgery)*
Alex Bui, Ph.D. *(Radiological Sciences)*
Thomas Chou, Ph.D. *(Biomathematics)*
Ian A. Cook, M.D. *(Psychiatry and Biobehavioral Sciences)*
James Dunn, M.D., Ph.D. *(Pediatric Surgery)*
Lee Goodglick, Ph.D. *(Pathology and Laboratory Medicine)*
Susan Harkema, Ph.D. *(Neurology)*
George Huang, D.Sc., D.D.S. *(Dentistry)*
Jack Judy, Ph.D. *(Electrical Engineering)*
Irwin Kurland, Ph.D. *(Medicine/Endocrinology)*
Sheila Nirenberg, Ph.D. *(Neurology)*
Dario Ringach, Ph.D. *(Neurobiology, Psychology)*
Felix Schweitzer, Ph.D. *(Neurobiology)*
Kang Ting, DMD, DM.Sc. *(Dentistry)*
Daniel J. Valentino, Ph.D. *(Radiological Sciences)*
Benjamin Wu, D.D.S., Ph.D. *(Materials Science and Engineering, Dentistry)*

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)*
Valeriy I. Nenov, Ph.D. *(Neurosurgery)*
Usha Sinha, Ph.D. *(Radiological Sciences)*
Imke Schroeder, Ph.D. *(Microbiology, Immunology, and Molecular Genetics)*

Adjunct Assistant Professors

Robert Close, Ph.D. *(Radiological Sciences)*
Robert J. Greenberg, 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 2002-03 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 36 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 (nine courses), followed by a comprehensive examination on the material covered in the five core courses in the area of study. Five of the nine 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.

Biomedical Engineering Ph.D.

The Ph.D. program prepares students for advanced study and research in biomedical engineering. Students must pass a written preliminary examination on the core courses, an oral qualifying/advancement to candidacy examination, and coursework for two minor fields of study and defend the dissertation. Each minor field consists of three 4-unit courses, of which two must be graduate (200-level) courses. One minor must be in another area of biomedical engineering, and the second minor should be outside 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

Students selecting bioacoustics, speech, and hearing as a minor field must take three courses, of which at least two must be graduate (200-level) courses, selected from Biomedical Engineering M214A, Electrical Engineering 114D, 214B, Linguistics 204.

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.

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 M196B, M296A, and one additional graduate-level elective from the additional foundations or electives list.

Core Courses (Required). Biomedical Engineering M196B, C201, CM202, CM203, M296A.

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

Electives. Biomathematics 206, CM208C, 220, M230, Biomedical Engineering M248, M296C, M296D, CM296L, Computer Science 161, 267B, Electrical Engineering 113, 132A, 151DL, 211A, 211B, M214A, 214B, 232E, M250A, M250B, 250C, 260A, 260B, Physics 210B, 231B.

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

The Ph.D. preliminary examination assesses the basic understanding of the material covered in the core courses. Students have the option of taking the examination either in the biomechanics, biomaterials, or tissue engineering subfield.

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

Electives. Biomedical Engineering C241L, C281, 282, Chemical Engineering 260, Chemistry and Biochemistry 153A, 153B, 153C, CM153G, CM155, M230B, CM253, CM255, M267, Civil and Environmental Engineering 235B, Materials Science and Engineering 150, 151, 160, 190, 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, M237, Physiological Science 215, 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, 257, 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 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.

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

Master's Degree. Students' backgrounds are evaluated to determine if they can proceed directly to the required courses. If their backgrounds are deficient in university-level mathematics, biochemistry, or microbiology, appropriate remedial coursework is assigned and approved by the field chair.

By the end of the first quarter in residence, new students are assigned a thesis adviser. Students present their first and second choices for thesis advisers to the field faculty who then meet to assign advisers based both on student preference and the research program constraints of the faculty. Also by the end of the first quarter in residence, students design a course program in consultation with their thesis adviser and get it approved by the field chair. The course program must include Biomedical Engineering C201, CM202, CM203, and two courses from M215, M225, CM245. Elective courses selected from the electives list (or approved by petition to the field chair) must be included in the course program to satisfy unit requirements.

Doctoral Degree. Students must design a course program in consultation with their dissertation adviser and get it approved by the field chair within one quarter of admission into the Ph.D. program. New students' backgrounds are evaluated to determine if they can proceed directly to the required courses. The course program must include Biomedical Engineering C201, CM202, CM203, and two courses from M215, M225, CM245. The 24 additional units required for the minor field may be composed of a combination of additional formal coursework and dissertation research units. It is strongly recommended that students include at least one three-course minor in their program.

After students have fulfilled the core course requirements (normally at the end of the first year in residence for students admitted directly to the Ph.D. program), they should petition the field chair to take the written Ph.D. examination administered by the molecular and cellular bioengineering faculty. Students are examined on the material covered in the core courses. Students who have a grade-point average above 3.25 and who are making satisfactory progress toward the degree are eligible to take the examination. Students who fail the examination may petition the field chair to retake the examination one time. Students who fail the examination may be dismissed from the program.

By the end of the third year in residence, Ph.D. students should advance to candidacy by passing the University Oral Qualifying Examination administered by a doctoral committee consisting of at least three field faculty (including the dissertation adviser) and at least one member from outside the field. The doctoral committee is appointed by the dean of the Graduate Division. A written Ph.D. proposition describing the student's dissertation work to date and plans for completion is presented to the doctoral committee. Subsequently, the student defends the proposition orally to satisfy the oral qualifying examination requirement. On the basis of the written and oral presentations, the doctoral committee assesses the student's qualifications for advancement to candidacy. Students who fail the examination may be dismissed from the program. A final oral defense of the dissertation is required. All Ph.D. students must complete and file a dissertation.

Core Courses (Required). Biomedical Engineering C201, CM202, CM203, and two courses from M215, M225, CM245.

Electives. Biomathematics 220, M270, Biomedical Engineering M196B, M296A, Chemistry and Biochemistry M230B, CM253, CM255, CM259A, CM259B, 262, M263, C265, M267, Microbiology, Immunology, and Molecular Genetics C233, CM248, M261, Molecular, Cell, and Developmental Biology CM220, M234, M237.

Neuroengineering

The neuroengineering field is a joint endeavor between the Neuroscience Interdepartmental Ph.D. Program in the 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; (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 nonengineering backgrounds are required to have taken courses in undergraduate calculus, differential equations, and linear algebra, in addition to at least a year of undergraduate courses in each of the following: organic chemistry and biochemistry, physics, and biology. Students lacking one or more requisite courses, if they are otherwise admissible, are provided an opportunity for appropriate coursework or tutorial during the summer before they enter the neuroengineering program.

Written Preliminary Examination. At the end of the first year, students take a written comprehensive examination in neuroengineering. The examination consists of three parts: (1) systems neuroscience, (2) biomedical engineering, and (3) a take-home 15-page proposal of a research topic, written as a grant proposal, in which students, under the guidance of faculty, propose solutions to a problem in neuroengineering that requires the integration of concepts and principles of engineering and neuroscience. The first two parts are answered in an examination room and are based on a reading list provided by the examination committee.

Oral Qualifying Examination. By the middle of the third year, students choose an individual advisory committee of four members, representing both neuroscience and engineering faculty, who serve as the dissertation committee. The committee provides advice on the conduct of the Ph.D. dissertation and administers the oral and final examinations. For the University Oral Qualifying Examination, students prepare and present a dissertation proposal, which must be approved by the dissertation committee before students advance to candidacy.

Final Oral Examination. When Ph.D. candidates complete dissertation research and write the dissertation, they meet with the committee to defend the thesis in the final oral examination.

Minors. Students have two minor fields of study. Those entering from biomedical engineering must have at least one minor in neuroscience (for example, molecular, cellular, systems, developmental, behavioral, or clinical neuroscience, or imaging in neuroscience), and those entering from neuroscience must have at least one minor in biomedical engineering (for example, biomedical signal and image processing and bioinformatics; bioacoustics, speech, and hearing; biomedical instrumentation; biomechanics, biomaterials, and tissue engineering; molecular and cellular bioengineering; biocybernetics). For all students, the remaining minor must be approved by the neuroengineering advising committee.

Students 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 M263A, M263B, Neuroscience M202.

Required Courses. Biomedical Engineering M260, M263A, M263B, 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, Electrical Engineering 250C, 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 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 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.

Upper Division Courses

C101. Introduction to Biomedical Engineering. (4) (Formerly numbered 101.) 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. Kabo (F)

CM102. Human Anatomy for Biomedical Engineers. (4) (Formerly numbered M102.) (Same as Physiological Science CM102.) Lecture, three hours; laboratory, two hours. Not open for credit to Physiological Science majors. Designed to provide foundation in human gross and microscopic anatomy for graduate biomedical engineering students. Broad overview of structural organization of human body and detailed examination of specific systems pertinent to biomedical research. Concurrently scheduled with course CM202. Letter grading. Mr. Montemagno (F)

CM103. Human Physiology for Biomedical Engineers. (4) (Formerly numbered M103.) (Same as Physiological Science CM103.) Lecture, three hours; laboratory, two hours. Not open for credit to Physiological Science majors. Designed to provide foundation in human physiology for graduate biomedical engineering students. Systematic approach to examination of major systems function, with emphasis on regulatory mechanisms controlling normal function. Detailed examination of specific systems pertinent to major areas of biomedical research. Concurrently scheduled with course CM203. Letter grading. Mr. Montemagno (W)

CM140. Introduction to Biomechanics. (4) (Formerly numbered M140.) (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)

M150L. Introduction to Micromachining and Microelectromechanical Systems Laboratory. (4) (Same as Electrical Engineering M150L and Mechanical and Aerospace Engineering M180L.) Lecture, three hours; laboratory, four hours; outside study, five hours. Requisites: Electrical Engineering 1 or Physics 1C, Chemistry 20A. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce a variety of MEMS, including microstructures, microsensors, and microactuators. Students fabricate set of basic MEMS structures in hands-on microfabrication laboratory. Letter grading. Mr. Judy (F)

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) (Formerly numbered M180.) (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)

M196A. Introduction to Cybernetics, Biomodeling, and Biomedical Computing. (2) (Same as Computer Science M196A and Cybernetics M196A.) 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)

M196B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science M196B, Cybernetics M196B, and Medicine M196B.) 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

CM196L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Same as Computer Science CM196L and Cybernetics M196L.) Lecture, two hours; laboratory, two hours. Requisite: course M196B. 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 CM296L. Letter grading. Mr. DiStefano

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. Kabo (F)

CM202. Human Anatomy for Biomedical Engineers. (4) (Same as Physiological Science CM204.) Lecture, three hours; laboratory, two hours. Not open for credit to Physiological Science majors. Designed to provide foundation in human gross and microscopic anatomy for graduate biomedical engineering students. Broad overview of structural organization of human body and detailed examination of specific systems pertinent to biomedical research. Concurrently scheduled with course CM102. Letter grading. Mr. Montemagno (F)

CM203. Human Physiology for Biomedical Engineers. (4) (Same as Physiological Science CM203.) Lecture, three hours; laboratory, two hours. Not open for credit to Physiological Science majors. Designed to provide foundation in human physiology for graduate biomedical engineering students. Systematic approach to examination of major systems function, with emphasis on regulatory mechanisms controlling normal function. Detailed examination of specific systems pertinent to major areas of biomedical research. Concurrently scheduled with course CM103. Letter grading. Mr. Montemagno (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; outside study, eight 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.

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)

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)

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; outside study, five 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.

M263A-M263B. Organization of Neural Systems. (4-4) (Same as Neuroscience M203A-M203B.) Lecture, three hours; discussion/laboratory, three hours. Integration of neuroanatomical and systems-level functional analysis of neural circuits leading to appreciation of their emergent properties. Discussion of organization of vertebrate central and peripheral nervous system based on cellular histological and regional analysis, highlighting contemporary experimental approaches. Topics include sensory processing, motor systems, physiological regulation, drive, learning, and neural basis of cognition. In Progress and letter grading.

C270. Energy-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Corequisite: course C270L. 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)

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 M196B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential (AP). Theory of AP propagation in 1D and 2D 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)

CM296L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Same as Computer Science CM296L.) Lecture, two hours; laboratory, two hours. Requisite: course M196B. 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 CM196L. Letter grading. Mr. DiStefano

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 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.

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 Engineering

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Vasilios I. Manousiouthakis, Ph.D., *Chair*
James C. Liao, Ph.D., *Vice Chair*

Professors

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.
Ken Nobe, Ph.D.
Selim M. Senkan, Ph.D.
A.R. Frank Wazzan, Ph.D. *(Dean Emeritus)*

Professors Emeriti

Eldon L. Knuth, Ph.D.
Lawrence B. Robinson, Ph.D.
William D. Van Vorst, Ph.D.

Associate Professor

Panagiotis D. Christofides, Ph.D.

Assistant Professors

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

Scope and Objectives

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

Chemical Engineering B.S.

The goal of the ABET-accredited chemical engineering curriculum is to provide 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 (196 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 Curricular Requirements on page 22 for details

Bioengineering Option

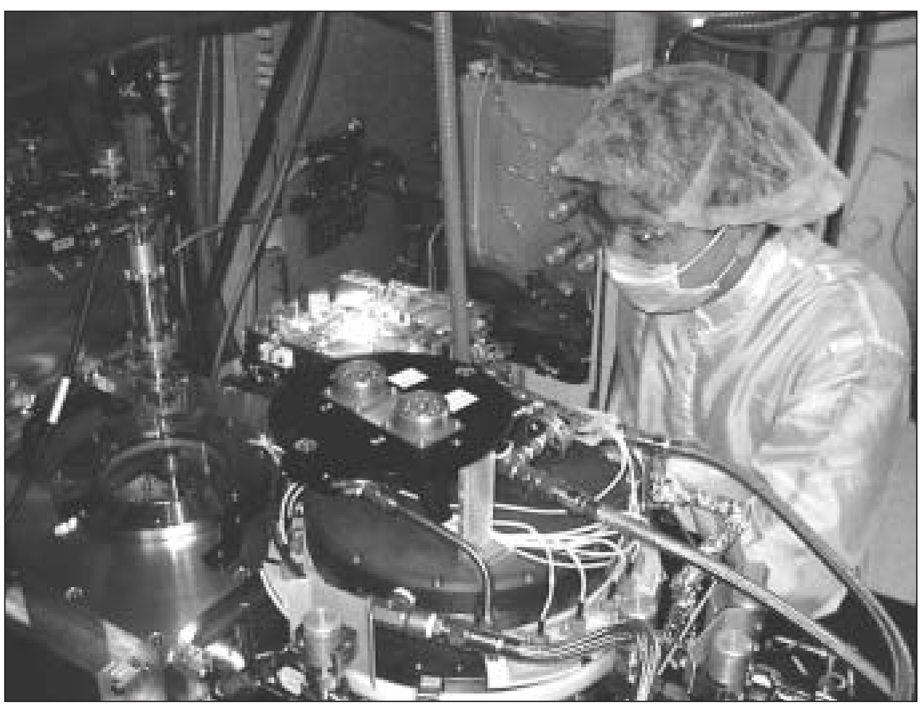
Course requirements are as follows (202 or 203 minimum units required):

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 microbiology, immunology, and molecular genetics or molecular, cell, and developmental biology or organismic biology, ecology, and evolution 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 Curricular Requirements on page 22 for details

Biomedical Engineering Option

Course requirements are as follows (200 or 201 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 microbiology, immunology, and molecular genetics or molecular, cell, and developmental biology or organismic biology, ecology, and evolution 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



An integrated chemical processing system for electronic material synthesis and processing.

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 22 for details

Environmental Option

Course requirements are as follows (200 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 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 Sciences M203A, Chemistry and Biochemistry 103, 110B, Environmental Health Sciences 240, 261, Organismic Biology, Ecology, and Evolution M127 (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 Curricular Requirements on page 22 for details

Semiconductor Manufacturing Option

Course requirements are as follows (200 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 Curricular Requirements on page 22 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 Engineering Department brochure.

The following introductory information is based on the 2002-03 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 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 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 which 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, 150, 160, 161L, 190, 191L, 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 Engineering Department. The third course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. All of these units must be in letter-graded 200-level courses. Students are encouraged to take more courses in their field of specialization. The minor field courses should be selected in consultation with the research adviser. A 3.33 grade-point average in graduate courses is required. A program of study to fulfill the course requirements must be submitted for approval to the departmental Student Affairs Office no later than one quarter after successful completion of the preliminary oral examination.

All Ph.D. students are required to enroll in the Chemical 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. Students are provided problems in writing and are then asked to solve them orally in front of a faculty committee. They are required to take Chemical Engineering 200, 210, and 220 in preparation for the examination. Students whose first degree is in chemical engineering take the examination at the end of the second quarter in residence. Students whose first degree is not in chemical engineering (for example, chemistry) 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 takes 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 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

Biochemical Engineering Laboratory

The Biochemical Engineering Laboratory is equipped for (1) aerobic or strictly anaerobic fermentations from the shake flask to 100-liter pilot-plant scale, (2) production, isolation, and purification of enzymes from recombinant or natural bacterial and yeast sources, (3) traditional enzymology as well as electroenzymology, and (4) production and characterization of biological and semisynthetic colloids such as micelles and vesicles. Both standard fermentations at mesophilic and extremophilic cultures at extremes of temperature (up to 100º C) and pH are conducted routinely. Environmentally controlled incubators are available for shake-flask studies. These cultures may be scaled to two- to three-liter batch or continuous fermenters such as the NBS Bioflow III or a custom high-temperature system. All fermenters are fully controlled and include automated feed and off-gas analysis. A unique, glass-lined steel 100-liter fermenter, which was designed and installed by UCLA biochemical engineers, is used for pilot-scale fermentations. Biomass may be harvested with a Beckman J2-21 Superspeed centrifuge, or for larger batches, with a steam-driven Sharples centrifuge. A 45-cubic-foot chromatography refrigerator, a large supply of chromatography columns and fittings, and ultrafiltration systems (batch and continuous hollow-fiber) are available for purifying enzymes.

Organic synthesis reactions catalyzed by electrochemically active redox enzymes such as cytochrome P450cam are studied using customized equipment for cyclic voltammetry, potential-step transient-decay analysis, and coulometry. Enzymes are studied in free aqueous solution and in membrane mimetic media such as micelles, vesicles, and adsorbed layers. A Wyatt Dawn F HeNe laser photometer is used to characterize micelles and vesicles.

Modern analytical equipment supports biochemical engineering research, including a Beckman DU-65 scanning spectrophotometer outfitted with a customized cuvette for spectroelectrochemical studies; two HPLCs, a Beckman and a Spectraphysics unit suitable for preparative-scale separations; and three gas chromatographs, one equipped with an electron capture detector.

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, electrodeposition 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 NO_x, 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 and MEMS systems. Areas of interest include novel dielectric materials, advanced thermal and plasma processing, surface and interface kinetics, and solid-state electronic devices 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 capability; advanced plasma processing tools including thin film deposition and etching; a surface analytical facility including X-ray photoemission spectroscopy, Auger electron spectroscopy, and ultra-violet photoelectron 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 electronic materials can be realized for applications in the next generation electronic devices and chemical or biological MEMS.

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, designd 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.

Optoelectronic Materials Processing Laboratory

The Optoelectronic Materials Processing Laboratory is equipped with state-of-the-art instruments for studying the molecular processes that occur during the organometallic vapor-phase epitaxy (OMVPE) of compound semiconductors. OMVPE is a key technology for synthesizing advanced electronic and optical devices, including solid-state lasers, infrared, visible, and ultraviolet detectors and emitters, solar cells, optical filters, heterojunction bipolar transistors, and high-electron mobility transistors. The laboratory houses several OMVPE reactors for the synthesis of III-V compound semiconductors. These are interfaced to mass and infrared spectrometers for in situ monitoring of surface and gas reactions. Computer codes have been developed to simulate the molecular chemical kinetics and transport phenomena taking place during film growth. In addition, the laboratory contains an ultrahigh vacuum system equipped with scanning tunneling microscopy low-energy electron diffraction; infrared spectroscopy and X-ray photoelectron spectroscopy; and effusive-beam dosers for the organometallic molecules. This apparatus characterizes the atomic structure of compound semiconductor surfaces (such as GaAs, InP, and related alloys) and determines the decomposition mechanisms and kinetics of organometallic molecules on these surfaces.

Knowledge gained from research in this laboratory may be used to develop new OMVPE processes for synthesizing high-performance optoelectronic devices.

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 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 laboratory is also equipped with a quartz crystal microbalance system for 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 also has a research-grade FTIR with a TGA interface, a thermogravimetric analysis system, and a dual column gas chromatograph. 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. Seven single and dual processor DEC Alpha and Compaq workstations form the basis of a local area network for the exclusive use of the laboratory. Access to SEASnet and campuswide computational facilities, such as an IBM SP2 cluster, is available to LAN users. 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.

Faculty Areas of Thesis Guidance

Professors

Yoram Cohen, Ph.D. (Delaware, 1981)
Chemical engineering: separation processes, graft polymerization, non-Newtonian fluids, macromolecular dynamics, pollutant transport and exposure assessment

James F. Davis, Ph.D. (Northwestern, 1981)
Intelligent systems in process, control operations, and design decision support systems, abnormal situation management, hazard analysis, data analysis, data interpretation, knowledge-based systems, knowledge databases, neural reasoning techniques, pattern recognition

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

Robert F. Hicks, Ph.D. (UC Berkeley, 1984)
Reaction engineering of organometallic vapor-phase epitaxy and surface chemistry of semiconductors

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

James C. Liao, Ph.D. (Wisconsin, Madison, 1987)
Chemical engineering: 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

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

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

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

Professors Emeriti

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

Lawrence B. Robinson, Ph.D. (Harvard, 1946)
Chemical engineering: thermodynamics, energy conversion devices and processes, transport phenomena in ionic media, phase transitions

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

Associate Professor

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

Assistant Professors

Jane P. Chang, Ph.D. (MIT, 1998)
Material processing, gas-phase and surface reactions, plasma enhanced chemistries, reaction engineering, process modeling, and MEMS-based chemical analysis

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

Lower Division Course

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)

Upper Division Courses

100. Introduction to Chemical 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 Laboratory. (6) Lecture, two hours; laboratory, eight hours; outside study, eight hours. Requisites or corequisites: course 104A, Electrical Engineering 2. 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. Presentation of student results in both written and oral form. Statistical design of experiments and error analysis. Letter grading. Ms. Chang (W,Sp)

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, Computer Science 10F. Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as an 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; outside study, eight 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; outside study, eight 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) (Formerly numbered 119.) 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

199. Special Studies. (2 to 8) Tutorial, to be arranged. Limited to seniors. Individual investigation of selected topic to be arranged with a faculty member. Enrollment request forms available in department office. Occasional field trips may be arranged. May be repeated for credit. 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; outside study, eight 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) (Formerly numbered C215.) (Same as Biomedical Engineering M215.) Lecture, four hours; outside study, eight 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) (Formerly numbered C225.) (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)

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

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

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.

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 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)

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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William W-G. Yeh, Ph.D., *Chair*
Jiun-Shyan Chen, Ph.D., *Vice Chair*
Patrick J. Fox, Ph.D., *Vice Chair*

Professors

Lewis P. Felton, Ph.D.
Jiann-Wen Ju, Ph.D.
Lawrence G. Selna, Ph.D.
Michael K. Stenstrom, Ph.D., *Associate Dean*
Keith D. Stolzenbach, Ph.D.
Mladen Vucetic, Ph.D.
William W-G. Yeh, Ph.D.

Professors Emeriti

Stanley B. Dong, Ph.D.
Michael E. Fourney, Ph.D.
Gary C. Hart, Ph.D.
Poul V. Lade, Ph.D.
Tung Hua Lin, D.Sc.
Chung Yen Liu, Ph.D.
Rokuro Muki, Ph.D.
Richard L. Perrine, Ph.D.
Moshe F. Rubinstein, Ph.D.
Lucien A. Schmit, Jr., M.S.

Associate Professors

Jiun-Shyan Chen, Ph.D.
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John W. Wallace, Ph.D.

Assistant Professors

Jonathan P. Stewart, Ph.D.
Ertugrul Taciroglu, Ph.D.

Senior Lecturers

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

Adjunct Professors

John A. Dracup, Ph.D.
Ne-Zheng Sun, Ph.D.

Adjunct Associate Professors

Joel P. Conte, Ph.D.
Daniel E. Pradel, Ph.D.
Thomas Sabol, Ph.D.

Scope and Objectives

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

Civil Engineering B.S.

The objective of the ABET-accredited civil engineering curriculum is to give graduating seniors an academically sound and practical background in civil engineering. A balanced program, including engineering science, design, and laboratory courses in civil engineering, is stressed. The ongoing goal of the program is to produce well-qualified graduates for the engineering profession or for graduate civil engineering schools in the U.S.

The Major

Course requirements are as follows (181 minimum units required):

1. Eight core courses: Chemical Engineering M105A or Mechanical and Aerospace Engineering M105A, Civil and Environmental Engineering 1, 108, Electrical Engineering 100, 103, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103
2. Civil and Environmental Engineering 120, 121, 130, 135A, 151, 153; one course involving a major design project from Civil and Environmental Engineering 135L, 144, 147, 157A, 157B, 157C; one mathematics course from Mechanical and Aerospace Engineering 174, 191A, 192A, 192B, 192C
3. Twenty-eight elective units, to be selected from the courses listed below, which must include 8 units of laboratory:

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

   Geotechnical Engineering. Civil and Environmental Engineering 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 150, 154, 155, 156A, 156B, 157A, 157B, 157C, 160, 163, 164, M166
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 Curricular Requirements on page 22 for details

Graduate Study

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

The following introductory information is based on the 2002-03 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, 150, 160, 161L, 190, 191L, 199; Mechanical and Aerospace Engineering 102, 103, M105A, 105D, 199.

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

Environmental Engineering

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

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

Elective Courses. Civil and Environmental Engineering 155, 157B, 157C, 163, 164, 253, 258A, 261, 265A, 265B; 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, 250A, 250B, 250C, 251, 252, 260, M262A, M262B, Chemical Engineering 101C or Mechanical and Aerospace Engineering 105D, Chemical Engineering 106, 210, C240, Computer Science 270A, 271A, 271B, Electrical Engineering 236A, 236B, 236C, Environmental Health Sciences 240, 252D, 255, 264, 410A, 410B.

The 2002 UCLA-ASCE concrete canoe team.

Geotechnical Engineering

Required Preparatory Courses. Civil and Environmental Engineering 108, 120, 121, 128L.

Required Graduate Courses. Civil and Environmental Engineering 220, 221, 222, 223, 228L.

Elective Courses. Civil and Environmental Engineering 135A, 142, 229, 235A, 235B, 235C, 250B, Earth and Space Sciences 139, Mechanical and Aerospace Engineering M256A.

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, 244.

Elective Courses. Civil and Environmental Engineering 120, 121, 130, 135C, 137, 142L, 143, 221, 222, 223, 232, 235B, 236, M237A, M240.

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. Civil and Environmental Engineering 130F, 130L, 135C, 137, M230B, 233, 234, 235C, M240, Mechanical and Aerospace Engineering 269B.

Water Resources Engineering

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

Required Graduate Courses. A minimum of five of the following courses: Civil and Environmental Engineering 250A, 250B, 250C, 251, 252, 253, 260, 265A, 265B.

Elective Courses. Civil and Environmental Engineering 150, 164, 255A, 255B; 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 Sciences M203A, 218, Computer Science 270A, 271A, 271B, Electrical Engineering 236A, 236B, 236C, M237, Environmental Health Sciences 225, 264, Mathematics 269A, 269B, 269C.

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

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, structural/earthquake engineering, structural mechanics, and water resources engineering.

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.

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.

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.

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 servohydraulic shaking tables (1.5 ft. x 1.5 ft. and 2 ft. x 4 ft.) are available to simulate the dynamic response of structures to base excitation such as earthquake ground motions.
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 servohydraulic 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 high-rises and retail buildings, this network, which is maintained by the U.S. Geological Society and State of California Division of Mines and Geology Strong Motion Program, represents the most detailed building instrumentation network in the world. The goal of the research conducted using the response of these buildings is to improve computer modeling methods and the ability of structural engineers to predict the performance of buildings during earthquakes.
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

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

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

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

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

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

Rokuro Muki, Ph.D. (Keio U., Japan, 1959)
Elasticity, mechanics of adhesive joints, asymptotic methods in applied mathematics

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

Associate Professors

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

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.

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

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

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

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

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

John A. Dracup, Ph.D. (UC Berkeley, 1966)
Water resources, hydrologic, and environmental systems analysis, civil engineering, engineering economics

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

Adjunct Associate Professors

Joel P. Conte, Ph.D., (UC Berkeley, 1990)
Analysis and modeling of structures with particular emphasis on the dynamic, nonlinear, and probabilistic aspects. Structural identification and control, experimental structural dynamics

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)

3. Fundamentals of Environmental Engineering Science. (4) Lecture, four hours; outside study, eight hours. Quantitative analysis of sources, transformations, and effects of pollutants in water, air, and soil. Topics include drinking water, wastewater, hazardous wastes, radioactive wastes, and atmospheric emissions. P/NP or letter grading. Mr. Stolzenbach (Sp)

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

Upper Division Courses

101. Statistics. (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 (W)

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)

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. Fox (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)

125. Fundamentals of Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 121, 137. Designed for seniors. Representations of earthquake ground motion, including response and Fourier spectra. Response of simple soil deposits and structures to ground motion. Hazard analysis by deterministic and probabilistic methods. Seismic design codes. 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. Felton, Mr. Ju (W)

130F. Experimental Fracture Mechanics. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite: course 108. Elementary introduction to fracture mechanics and experimental techniques used in fracture, crack tip stress fields, strain energy release rate, fracture characterization, compliance calibration, surface flaws, fatigue crack growth and fatigue life of structural components, mixed mode fracture, and individual projects. Letter grading.
Mr. Ju (W, alternate years)

130L. Experimental Structural Mechanics. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 130. Lecture and experiments in limit analysis of various aspects of structures. Elastic and plastic analysis of structural elements in multiaxial stress states. Buckling of columns, plates, and shells. Effects of actual boundary conditions on structural performance. Evaluation of structural fasteners. Letter grading. Mr. Ju (W)

135A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 11, 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. Felton, Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; outside study, eight 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. Felton, 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, iosparametric 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. Felton (Sp)

137. Elementary Structural Dynamics. (4) Lecture, four hours; outside study, eight 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; outside study, eight hours. Requisite: course 135B. 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. Letter grading. Mr. Ju (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. Requisite: course 142. Limited enrollment. Design considerations used for reinforced concrete beams, columns, slabs, and joints evaluated using analysis and experiments. Links between technical theory, building codes, and experimental results. Letter grading. Mr. Wallace (Sp)

143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; outside study, eight 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. Selna (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. Requisite: course 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. Engineering Hydrology. (4) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 103. Recommended: elementary probability. Precipitation, climatology, stream flow analysis, flood frequency analysis, groundwater, snow hydrology, hydrologic simulation. Possible field trips. Letter grading. Mr. Yeh (F)

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; outside study, eight 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. Mr. Yeh (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. Introduction to Environmental Aquatic Chemistry. (4) Lecture, four hours; outside study, eight hours. Requisites: course 153, Chemistry 20A, 20B, Mathematics 31A, 31B, Physics 1A, 1B. Description of chemical behavior of metals and anthropogenic/natural inorganic/organic compounds in natural fresh/marine surface waters and water treatment; acid-base chemistry, alkalinity, complexation, precipitation, sorption, redox, photochemistry, disinfection by-products, ozonation. Selected global chemical cycle(s). Letter grading. Mr. Stenstrom (W)

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. Harmon (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)

157A. Design of Water Resource Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: course 151, Mechanical and Aerospace Engineering 103. Review design of hydraulic structures, pertinent fluid mechanics, and hydraulic theory and applications. Examples of failures and successes of hydraulic structures. Class project and field trip required. Letter grading. Mr. Yeh (Sp)

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)

160. Environmental Monitoring and Data Analysis. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 11, 15, 153, Mathematics 32A, 33A. Random and multistage sampling of environmental systems, empirical models and curve fitting, estimation of trends and statistical parameters, regression and correlation, factor analysis of multivariate data, kriging, monitoring network design and field experimental design, visual representation and computational mapping of environmental data. Letter grading. Mr. Stenstrom (F)

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. Mr. Harmon (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. Mr. Harmon (F)

166L. Environmental Microbiology and Biotechnology Laboratory. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; outside study, four hours. Requisite: course 166. 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. Mr. Harmon (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)

199. Special Studies. (2 to 8) Tutorial, to be arranged. Limited to seniors. Individual investigation of selected topic to be arranged with a faculty member. Enrollment request forms available in department office. Occasional field trips may be arranged. May be repeated for credit. 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 (Sp)

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 (F)

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. Fox (Sp)

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 (W)

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 (W)

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. Fox (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 (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)

229. Seminar: Advanced Topics in Soil Mechanics. (4) Seminar, four hours; outside study, eight hours. Topics may vary each term to cover subjects such as earth dam design, seepage through soils, consolidation, constitutive laws, finite difference and finite element methods with special application in soil mechanics, theories of elasticity and plasticity, and case histories. Letter grading. Mr. Vucetic (W)

M230A. Mechanics of Deformable Solids. (4) (Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 156A. Kinematics of deformation, strain, tensors, invariance, compatibility; conservation laws; stress tensors; equations of motion; boundary conditions; constitutive equations: general theory, linearization, anisotropy; reciprocity linear isotropic elastic problems, plane and generalized plane problems; dynamic problems. 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. Equations of linear elasticity; uniqueness of solution; Betti/Rayleigh reciprocity; Saint-Venant's principle; simple problems involving spheres and cylinders; special techniques for plane problems. Airy's stress function, complex variable method, transform method; three-dimensional problems, torsion, entire space and half-space problems; boundary integral equations. 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 M230, 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. Felton, 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, Mr. Ju (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. Ju (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)

M240. Optimum Structural Design. (4) (Same as Mechanical and Aerospace Engineering M267A.) Lecture, four hours; outside study, eight hours. Requisite: course 235A or Mechanical and Aerospace Engineering 261A. Synthesis of structural systems; analysis and design as optimization problems; techniques for synthesis and optimization; application to aerospace and civil structures. Letter grading. Mr. Felton (W)

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

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. Selna (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) (Formerly numbered 243.) 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 components of hydrologic cycle. Hydrologic mass balance analysis, hydrologic error analysis using systems investigation and physical hydrology. Stochastic hydrology: time-series analysis, Markovian streamflow generating models, and generation of multivariate synthetic streamflows. Applications. Letter grading. Mr. Yeh (W)

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. Mathematical Modeling of Contaminant Transport in Groundwater. (4) 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)

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

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. Harmon (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, 251. 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)

M262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric 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 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) (Formerly numbered 263.) 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. Harmon (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. Harmon (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. Mr. Harmon (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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Wesley W. Chu, Ph.D.
Jason (Jinsheng) Cong, Ph.D.
Joseph J. DiStefano III, Ph.D.
Michael G. Dyer, Ph.D.
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Deborah L. Estrin, Ph.D.
Mario Gerla, Ph.D.
Sheila A. Greibach, Ph.D.
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Richard R. Muntz, Ph.D.
D. Stott Parker, Jr., Ph.D.
Miodrag Potkonjak, Ph.D.
Majid Sarrafzadeh, Ph.D.
Carlo Zaniolo, Ph.D. *(Norman E. Friedmann Professor of Knowledge Sciences)*
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.
Elias Koutsoupias, Ph.D.
David A. Rennels, Ph.D.
Stefano Soatto, Ph.D.
Yuval Tamir, Ph.D.

Assistant Professors

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Petros Faloutsos, Ph.D.
Songwu Lu, Ph.D.
Glenn Reinman, Ph.D.

Senior Lecturer

Leon Levine, M.S., *Emeritus*

Adjunct Professors

Andrew B. Kahng, Ph.D.
Boris Kogan, Ph.D.
Gerald J. Popek, Ph.D.

Adjunct Associate Professors

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

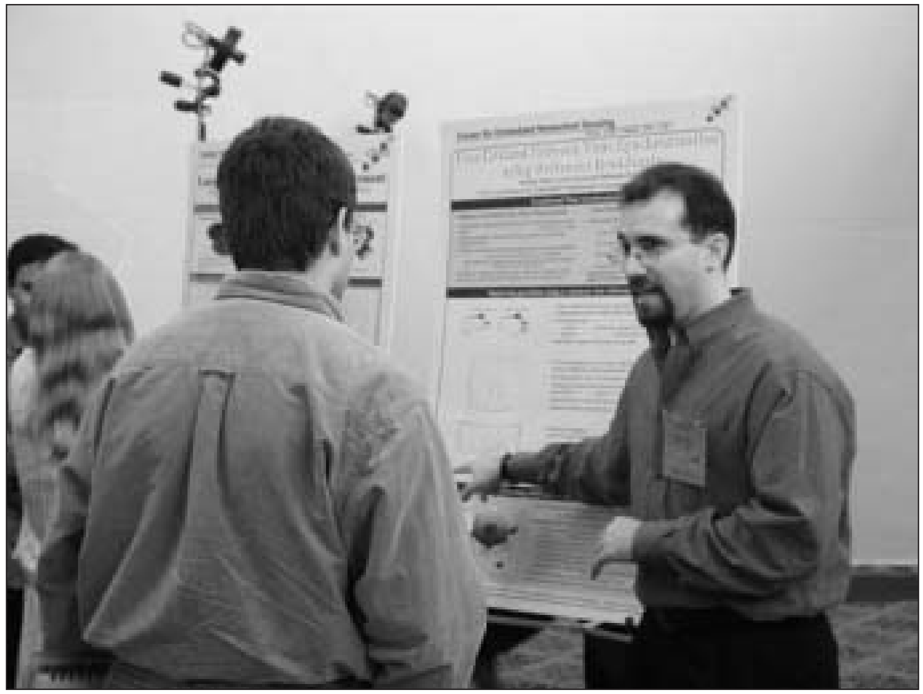
Scope and Objectives

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

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 nearly a dozen laboratories specializing in areas such as distributed systems, multimedia computer communications, VLSI systems, VLSI CAD, and artificial intelligence. Also, the Cognitive Systems Laboratory is engaged in studying computer systems which 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).



Poster session at the Computer Science Department Research Review

Computer Science and Engineering B.S.

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

The computer science and engineering curriculum is accredited by the Computing Accreditation Commission 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); one computer science/electrical engineering elective (excluding Electrical Engineering 100)
3. Four upper division elective courses from the Computer Science Department. Course 199 may normally be taken only as a free elective; 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 Curricular Requirements on page 22 for details. Computer Science and Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 194 or 195, which may be applied toward either the humanities or social sciences section of the GE requirements

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)
3. Two 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 sciences, biology, chemical 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 Curricular Requirements on page 22 for details. Computer Science majors must also select two additional humanities/social sciences courses and one additional life sciences course and are required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 194 or 195, which may be applied toward either the humanities or social sciences section of the GE requirements. Chemistry 20A may be substituted for one of the life sciences courses

Graduate Study

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

The following introductory information is based on the 2002-03 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, 150, 160, 161L, 190, 191L, 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, 171 or 174.

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. The remaining two courses may 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 a 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; computer networks; computer science theory; computer system architecture; information and data management; scientific computing (biomedical engineering systems and biocybernetics, physical systems); software systems and languages.

Course Requirements

Course Requirement. There is no formal course requirement for the Ph.D. degree, and students may theoretically take required Ph.D. program examinations without taking courses. 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 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, plus the current literature in the area of specialization. A detailed syllabus for each major field can be obtained from the Student Affairs Office in the Computer Science Department. Each minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. By petition and administrative approval, a minor field may be satisfied by examination.

Breadth Requirement. 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, 171 or 174.

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 preliminary examination. When the examination is passed and all coursework is completed, students may be required to take an oral preliminary examination that encompasses the major and minor fields. The examination may be waived by the faculty on the recommendation of the major field committee for students deemed to be making strong progress toward the degree. Students may not take a preliminary examination more than twice.

After passing the preliminary 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

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 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.

Areas Included in the Computer Networks Field

Typical Systems Studied

- Computer networks
- Packet switching
- Multiprogramming systems
- Parallel processing systems
- High-performance computers
- Distributed processing systems
- Time-shared systems
- Satellite and ground radio packet switching systems
- Cellular radio systems
- Personal communication networks
- Local-area networks
- Communication processors
- High-speed networks
- Photonic networks
- Neural networks
- Communication protocols
- Network control procedures (centralized and distributed)
- Mobile networks

Tools Used

- Probability theory
- Queueing theory
- Queueing networks
- Graph theory
- Network flow theory
- Optimization theory
- Mathematical programming
- Heuristic design algorithms
- Simulation
- Distributed algorithms
- Measurement
- Information theory
- Control theory

The term theoretical computer science has come to be applied nationally and internationally 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.

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

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.

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 distributed processing, programming languages, and 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 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 information.

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 become more complex, involving more complicated decisions and trade-offs among decisions, the need for sophisticated information and data management will become essential.

Scientific Computing

The scientific computing field currently covers one area of specialization: biomedical systems, which can be selected as a major or minor field for the Ph.D. in Computer Science.

Subject Matter and Course Offerings

Biomedical Systems. Emphasis is on modeling methodologies, algorithms, and quantitative methods for life sciences applications, both basic and applied. Research topics typically involve one or more of the following areas: (1) organismic, cellular, and mechanism-level mathematical modeling and simulation of cancer and disease processes, (2) advances in modeling methodology for life sciences research, including experiment design optimization, (3) development of software for modeling (model fitting and model selection) and kinetic analysis of biological systems, with emphasis on expert systems, graphical, and web interfaces, (4) model-based experimental research in physiology, pharmacology, biochemistry, genomics, bioinformatics, and related fields, developing the interface between (theoretical) modeling and laboratory experimentation.

Software Systems and Languages

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. UCLA places particular emphasis on the area of parallel and distributed systems.

Facilities

Departmental laboratory facilities for instruction and research include:

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

Biocybernetics Laboratory. For interdisciplinary experimental and computational problems in physiology, medicine, and pharmacology. Laboratory pedagogy involves development and exploitation of the synergistic and methodologic interface between modeling and laboratory experimentation, emphasizing 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

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

Computer Communications Laboratory. For investigating local-area networks, packet-switching networks, and packet-radio networks

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/

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

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/

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

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/

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/

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/

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/

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://kmed-www.cs.ucla.edu/

Laboratory for Embedded Collaborative Systems. 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/

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

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/

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/

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

UCLA Vision Laboratory. For research involving processing of visual information to retrieve mathematical models of the environment in order for humans and machines to interact with it. Applications include image-based rendering for virtual reality, archaeology, CAD, guidance of autonomous vehicles, human/computer interaction, visualization, and recognition. See http://www.vision.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/

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/

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 (HSSEASnet).

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 campus-wide Academic Technology Services. Access to the departmental and HSSEASnet 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)
Distributed algorithms, concurrent programming languages, simulation, performance evaluation of distributed systems

Alfonso F. Cardenas, Ph.D. (UCLA, 1969)
Data management systems, programming languages and software systems, digital simulations, systems analysis, management information systems, computing economics and management

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 (Jinsheng) 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, bioengineering, biosystems, modeling and simulation, modeling theory and methodology, artificial intelligence/ knowledge-based systems, dynamic systems optimization, estimation, identification, and control

Michael G. Dyer, Ph.D. (Yale, 1982)
Artificial intelligence, natural language processing, cognitive modeling

Milos D. Ercegovac, Ph.D. (Illinois, 1975)
Computer systems architecture, digital computer arithmetic, logic design, functional languages and architectures, VLSI algorithms and structures

Deborah L. Estrin, Ph.D. (MIT, 1985)
Computer networks, network embedded systems, sensor 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)
Artificial intelligence

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

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

* Also Professor of Medicine

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 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)
Decision analysis, human information processing, artificial intelligence, pattern recognition, man/machine interface, mathematical analysis of systems, complexity of computations

†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 reasoning under uncertainty with emphasis on Baysian networks, structure-driven inference algorithms and knowledge-based compilation techniques. Unifying foundation for logical and probabilistic reasoning. Belief revision and causality. Applications to model-based diagnosis and reasoning about physical systems

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

Elias Koutsoupias, Ph.D. (UC San Diego, 1994)
Decision making under uncertainty, computational geometry, randomized algorithms, combinatorial optimization and computational complexity

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

† Member of Brain Research Institute

Stefano Soatto, Ph.D. (Cal Tech, 1996)
Vision, control system theory, estimation theory, real-time sensory processing and machine interfaces

Yuval Tamir, Ph.D. (UC Berkeley, 1985)
Computer architecture, VLS

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

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

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

Senior Lecturer

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

Adjunct Professors

Andrew B. Kahng, Ph.D. (UC San Diego, 1989)
Complexity theory, parallel algorithms and architectures, VLSI layout, computational geometry

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

Adjunct Associate Professors

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

Peter L. Reiher, Ph.D. (UCLA, 1987)
Optimistic replication, optimistic concurrency control mechanisms for parallel and distributed systems, distributed systems

Lower Division Courses

1. Principles of Computer Science. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Not open for credit to Computer Science majors. Introduction to fundamental scientific principles of computation. Programming in LISP. Systems software, including interpreters, and operating systems. Computer hardware design and implementation. Theory of computation, including computability and complexity. Applications, including artificial intelligence and scientific computing. P/NP or letter grading. Mr. Korf

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)

10C. Introduction to Programming. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Exposure to computer organization and capabilities. Basic principles of programming: algorithmic, procedural problem solving. Program design and development. Control structures and data structures. Character strings and word processing. Letter grading. Mr. Gerla, Mr. Rennels

10F. Introduction to Programming/FORTRAN. (4) Lecture, four hours; discussion, two hours. Open to Mathematics and Computer Science majors; open to graduate students on S/U grading basis only. Description and use of FORTRAN programming language. Selected topics in programming techniques. Programming and running of several problems. Letter grading. Mr. Gerla

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. Cong (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. Not open to students with credit for former course 23. 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. Koutsoupias (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. Potkonjak (F,Sp)

M51A. Logic Design of Digital Systems. (4) (Formerly numbered 51A.) (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 (F,W,Sp)

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. Muntz (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. Gafni (F,Sp)

117. Computer Networks: Physical Layer. (6) 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. Recommended: course 111. Designed for juniors/seniors. Investigation of functions required to operate computer communications networks. Development of methodology for implementing these functions in procedures called protocols. Organization around ISO-OSI seven-layer architecture, with review of each layer. Specific functions defined and available alternatives studied. Presentation of several applications and case studies based on existing public and private networks. 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. Cardenas, Mr. Chu (W)

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 32, 33. Study, comparison, and evaluation of alternative strategies for language specification, data description, data control, program modularity, instruction sequencing, and language implementations. Use of a few languages selected from FORTRAN 77, ADA, SNOBOL 14, LISP, MODULA 2, and PROLOG to illustrate particular implementations of some of above features. Letter grading. Mr. Bagrodia (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. Darwiche (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 (W)

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. Cong, Mr. Rennels, 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 (W, odd years)

M152A. Introductory Digital Design Laboratory. (2) (Formerly numbered 152A.) (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) (Formerly numbered 152B.) (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. 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)

171. Real-Time Computer Systems. (4) Lecture, four hours; outside study, eight hours. Designed for seniors. Survey of fundamentals, with emphasis on hardware and systems concepts. Adapting digital computers to interfaces, including multiprogramming, bus structure, interrupt, and time-sharing considerations. Digital communication, remote consoles, sampling, quantizing, multiplexing, analog-digital conversion, and data reconstruction. Letter grading.
Mr. Carlyle, Mr. Karplus (F, Sp)

M171L. Data Communication Systems Laboratory. (2 to 4) (Formerly numbered 171L.) (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)

174. Elements of Computer Graphics. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Requisite: course 32. Hardware and software elements of computer graphics systems. Graphics languages. Graphic workstations and specialized input/output (I/O) devices. Design and development of interactive graphics programs. Letter grading.
Mr. Muntz (W,Sp)

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.
Ms. Greibach (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 (F,W,Sp)

190. Computer Science Design Project. (4) Lecture, four hours; outside study, eight hours. Preparation: adequate background in hardware, software, and computer applications. Limited to senior Computer Science and Engineering majors and senior Computer Science majors. Basic concepts of design of projects in computer science, including interpretation of specifications, subtasking, design of experiments, data analysis and performance evaluation, cost engineering, reliability, and societal and safety considerations. Letter grading. Mr. Klinger (Sp)

M196A. Introduction to Cybernetics, Biomodeling, and Biomedical Computing. (2) (Formerly numbered 196A.) (Same as Biomedical Engineering M196A and Cybernetics M196A.) 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)

M196B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Biomedical Engineering M196B, Cybernetics M196B, and Medicine M196B.) 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 (Sp)

CM196L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Same as Biomedical Engineering CM196L and Cybernetics M196L.) Lecture, two hours; laboratory, two hours. Requisite: course M196B. 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 CM296L. Letter grading. Mr. Distefano

199. Special Studies. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Individual investigation of selected topic to be arranged with a faculty member. Enrollment request forms available in department office. Occasional field trips may be arranged. May be repeated for credit. 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. Mr. 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

213. Distributed Embedded Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 118. Designed for graduate students. Important class of distributed networks are those that support monitoring and manipulation of physical spaces through wireless sensor networks. Study of distributed protocols needed to realize these systems. Topics include design implications of energy and otherwise resource-constrained nodes, network self-configuration and adaptation, localization and time synchronization, programming paradigm, applications, and usage issues such as human interfaces, safety, and security. Letter grading. Ms. Estrin (W)

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

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

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) (Formerly numbered 249.) 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; recitation, 30 minutes; laboratory, one hour; outside study, eight hours. Requisite: course 143. Object and database principles. Data models and accessing. Database systems architecture and functional components. Extended relational systems. Object and semantic systems. Systems comparison. Database design, organization, indexing, and performance. Other topics at discretion of instructor. Letter grading. Mr. Cardenas

241B. Pictorial and Multimedia Database Systems. (4) Lecture, three and one-half hours; recitation, 30 minutes; outside study, nine hours. Requisites: courses 143, 241A. Pictorial and multimedia information system requirements. Data models and accessing; alternatives. Database systems. Visual languages and communication. Hypertext. Database design and organization, logical and physical. Database 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

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)

253B. Advanced Topics in Fault-Tolerant Computing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 253A. Fault tolerance in distributed systems: protocols and network redundancy. Design of fault-tolerant software: N-version programming and recovery blocks. Relationship between fault tolerance and system security. Case studies of contemporary fault-tolerant systems. Review of recent research results. Letter grading. Mr. Rennels (Sp)

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. LSI in Computer System Design. (4) (Same as Electrical Engineering M216A.) Lecture, four hours; laboratory, four hours. Limited to graduate computer science and electrical engineering students. 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 and S/U or letter grading. Mr. Rennels

258D. VLSI CAD Techniques. (4) Lecture, four hours; outside study, eight hours. Designed for graduate computer science and electrical engineering students. In-depth study of latest advances in computer-aided VLSI design techniques, including building block layout, placement and routing algorithms, simulation, design verification and timing, analog/digital synthesis techniques, testing, silicon compilation, expert system applications, and automatic performance optimization. Letter grading.

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 23. Examination in depth of that part of artificial intelligence concerned with problem-solving behavior, including problem spaces, brute-force search, heuristic search, two-player game searches, planning, subgoaling, GPS, macro-operators, and abstraction. Emphasis on mathematical rigor and complexity analyses of search algorithms. 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) (Formerly numbered 262C.) (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

268CN. Computational Neuroscience. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Computational neuroscience as a paradigm of formal analysis and demonstrations of how to correctly interpret sensory data by discovering constraints from the natural world. Neural networks and connectionist models as a paradigm for parallel and concurrent computation and application to problem of vision, multimodal sensory interpretation, and learning. Letter grading.

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.

276A. Pattern Analysis and Machine Intelligence. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Fundamentals of pattern recognition, feature extraction and selection, autonomous learning, clustering, and machine intelligence. Letter grading. Mr. Klinger

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 276A 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

282A. Cryptography. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Basics of cryptography: symmetric and asymmetric cryptosystems; DES, RSA, ElGamal, elliptic curves. Schemes for signature, key distribution and key agreement, identification, authentication, and secret sharing. Advanced topics may include pseudo-random number generation, zero-knowledge proofs, and oblivious traffic. Letter grading. Mr. Gafni

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

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. Koutsoupias (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. Koutsoupias

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 M196B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential (AP). Theory of AP propagation in 1D and 2D 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)

CM296L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Formerly numbered C296L.) (Same as Biomedical Engineering CM296L.) Lecture, two hours; laboratory, two hours. Requisite: course M196B. 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 CM196L. Letter grading. Mr. DiStefano

298. Research Seminar: Computer Science. (2 to 4) (Formerly numbered 209AA-209ZZ.) 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 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; 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 and S/U or letter 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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Professors

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Abeer A.H. Alwan, Ph.D.
A.V. Balakrishnan, Ph.D.
Elliott R. Brown, Ph.D.
Frank M.C. Chang, Ph.D.
Harold R. Fetterman, Ph.D.
Michael P. Fitz, Ph.D.
Warren S. Grundfest, M.D., FACS
Tatsuo Itoh, Ph.D. (*TRW Professor of Electrical Engineering*)
Stephen E. Jacobsen, Ph.D., *Associate Dean*
Rajeev Jain, Ph.D.
Bahram Jalali, Ph.D.
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Eli Yablonovitch, Ph.D.
Kung Yao, Ph.D.

Professors Emeriti

Frederick G. Allen, Ph.D.
Francis F. Chen, Ph.D. *(Research Professor)*
Robert S. Elliott, Ph.D.
Richard E. Mortensen, Ph.D.
H.J. Orchard, M.Sc.
Frederick W. Schott, Ph.D.
Gabor C. Temes, Ph.D.
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Associate Professors

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Fernando G. Paganini, Ph.D.
Mani B. Srivastava, Ph.D.
Lieven Vandenberghe, Ph.D.
Ingrid M. Verbauwhede, Ph.D.
Richard D. Wesel, Ph.D.

Assistant Professors

Lei He, Ph.D.
Jack W. Judy, Ph.D.
C.-K. Ken Yang, Ph.D.

Adjunct Professors

Nicolaos G. Alexopoulos, Ph.D.
Donald Arnush, Ph.D.
Giorgio Franceschetti, Ph.D.
Paul T. Greiling, Ph.D.
Brian H. Kolner, Ph.D.
Neville C. Luhmann, Jr., Ph.D.
Joel Schulman, Ph.D.
Pyotr Y. Ufimtsev, Ph.D.

Adjunct Associate Professors

Bijan Houshmand, Ph.D.
Kenneth W. Iliff, Ph.D.

Adjunct Assistant Professors

Charles Chien, Ph.D.
Robert J. Greenberg. Ph.D.

Scope And Objectives

The Electrical Engineering Department emphasizes teaching and research in the fields of communications and telecommunications, control systems, electromagnetics, engineering optimization/ operations research, integrated circuits and systems, 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 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.

Laboratories are available for research in the following areas: analog and digital electronics, hybrid integrated circuits, integrated semiconductor devices, microwave and millimeter wave electronics, solid-state electronics, fiber optics, lasers and quantum electronics, and applied plasma physics. The department is associated with the Center for High-Frequency Electronics and the Institute of Plasma and Fusion Research, two research centers at UCLA.

Electrical Engineering B.S.

The ABET-accredited electrical engineering curriculum gives an excellent background for either graduate study or employment. The two main objectives are to provide (1) a deep and fundamental education in electrical engineering as well as in basic sciences and mathematics and (2) specialized education in one branch of electrical engineering so that students develop expertise in it.

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 192A
3. Any five major field elective courses selected from those offered by the Electrical Engineering Department, including at minimum 4 units of laboratories and one design course; 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 Curricular Requirements on page 22 for details. Electrical Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 194 or 195, which may be applied toward either the humanities or social sciences section of the GE requirements

Biomedical Engineering Option

Course requirements are as follows (199 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, 192A
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 M196B, CM196L, 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 Curricular Requirements on page 22 for details. Electrical Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 194 or 195, which may be applied toward either the humanities or social sciences section of the GE requirements

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 192A
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 Curricular Requirements on page 22 for details. Electrical engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 194 or 195, which may be applied toward either the humanities or social sciences section of the GE requirements

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 2002-03 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 all three B.S. options in Electrical Engineering cannot be applied toward graduate degrees. Required courses listed in only one or two of the options may, in some circumstances, be applied toward a graduate degree but require a petition.

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, 150, 160, 161L, 190, 191L, 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, 172, M185.

Group II: Electrical Engineering 221C, 260A, 260B, 261, 262, 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.

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, 202A, 204A.

Group II: Electrical Engineering 206A, 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, 115C, and 121A.

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.

Group I: Electrical Engineering 215A, 215B, M216A.

Group II: Electrical Engineering 212A, 212B, 213A, 215C, 215D, 221A, 221B.

Group III: Computer Science 251A, 252A, 258D.

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.

Photonics and Optoelectronics

Requisite. B.S. degree in Engineering or Physics or equivalent.

Thesis Plan. Electrical Engineering 270, 271, either 272 or 273, 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, and six additional courses, of which at least two must be 200-level courses.

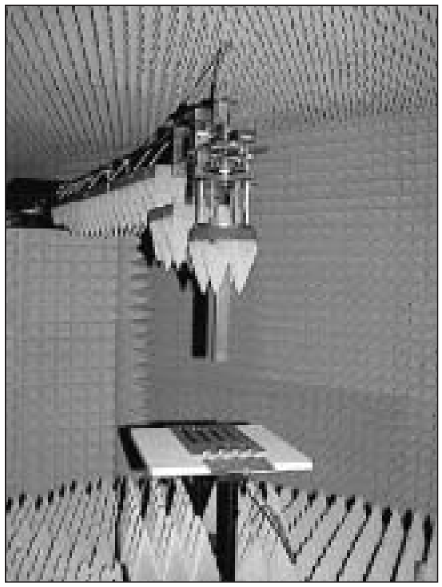
Additional Courses. With a few exceptions, all 100- and 200-level courses in the *UCLA General Catalog* are acceptable subject to the approval of the adviser. The exceptions are the following courses (which are not acceptable for any M.S. program in Electrical Engineering): (1) all school undergraduate 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



Leaky-wave antenna in bipolar planar near-field measurement chamber

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, 122AL, 123A, 123B, 124, 162A, 163A, 163B, 164AL, 172, M208A, M208B, 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

The comprehensive examination plan is not offered.

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.

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; 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 each of the two minor fields, 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 waveguiding 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, novel time domain methods in microelectromechanics, 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, microelectromechanical systems, 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; networking electronics; distributed sensors with wireless networking; 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/.

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, and MESFETs, as well as more conventional scaled-down MOSFETs, SOI devices, bipolar devices, and photovoltaic devices. The studies of basic materials, submicron structures, and device principles range from Si, SiGe, 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.

Microelectromechanical Systems

The microelectromechanical systems (MEMS) 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 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 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.

Nanoelectronics Research Facility

The state-of-the-art Nanoelectronics Research Facility for graduate research and teaching as well as the undergraduate microelectronics teaching laboratory are housed in an 8,500-square-foot class 100 / class 1000 clean room with a full complement of utilities, including high purity deionized water, high purity nitrogen, and exhaust scrubbers. The NRF supports research on nanometer-scale fabrication and on the study of fundamental quantum size effects, as well as exploration of innovative nanometer-scale device concepts. The laboratory also supports many other schoolwide programs in device fabrication, such as MEMS and optoelectronics. For more information, see http://www.nanolab.ucla.edu/.

Photonics and Optoelectronics Laboratories

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

The Photonics and Optoelectronics Laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrafast lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al_2O_3 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.

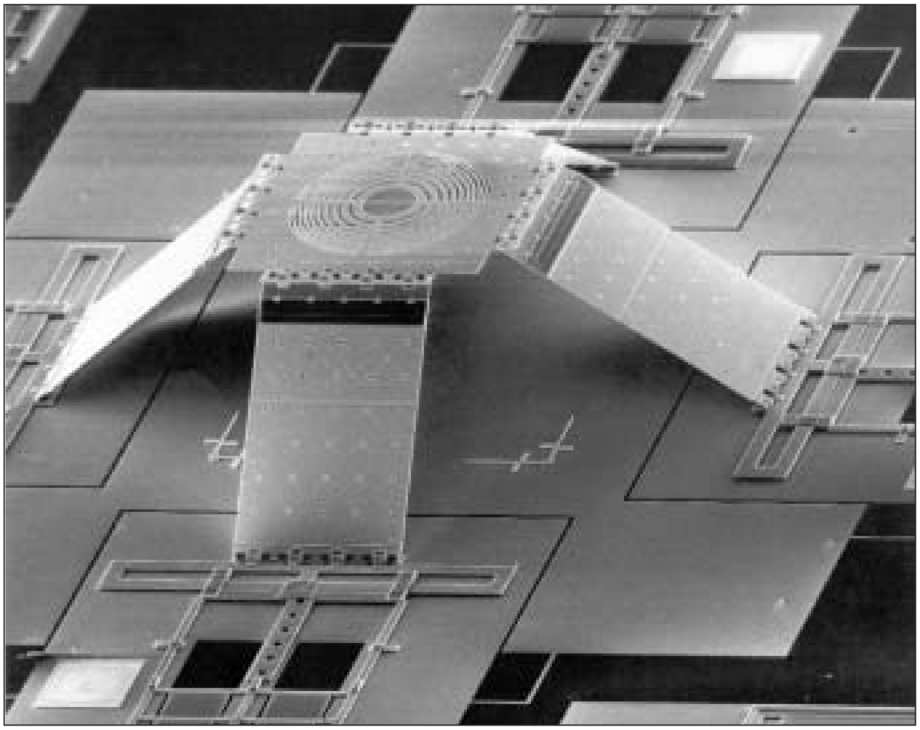
Plasma Electronics Facilities

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 (T^3) 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 CO_2 laser in the U.S. It can produce 200J, 170ps pulses of CO_2 radiation, focusable to 10^{16} W/cm^2. 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,



Microlens with integrated XYZ micropositioning stage made by microelectromechanical systems technology

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.

Wireless Communications Research Group

The Wireless Communications Research Group is interdisciplinary and brings together expertise in sensors, signal processing, integrated circuits, computer networking, RF design, digital communication, and antenna design. The aim of this group is to investigate the design, fabrication, and deployment of wireless communication systems for sensor-based monitoring, as well as speech, video, and computer data networking. The signal processing element focuses on compression of speech (Professor Abeer A.H. Alwan) and video (Professor John D. Villasenor) information for efficient utilization of radio bandwidth. Wireless sensor research focuses on very low-power systems (Professors William J. Kaiser, Oscar M. Stafsudd, and Gregory J. Pottie) for collecting, analyzing, and interpreting sensor data through wireless networking. The integrated circuits element concentrates on design of radio frequency analog circuits (Professors Asad A. Abidi and Behzad Razavi) and digital modem circuits (Professor Babak Daneshrad) for integrated radios. Networking research (Professor Mani B. Srivastava) is aimed at developing new network control techniques for reducing power consumption and adapting to mobility and bandwidth limitations in wireless environments. The digital communications effort (Professors Gregory J. Pottie and Babak Daneshrad) is creating new system design techniques for communication devices that reduce power consumption and improve performance by exploiting fundamental advances in modulation and coding theory. The antenna design research (Professor Yahya Rahmat-Samii) is creating new integrated structures for improved sensitivity and radiation patterns.

The Wireless Communications Research Group has a very strong focus on applying basic research in each of the above domains to building practical wireless systems that address the future needs of society in providing every citizen with access to worldwide computer networks and databases, as well as providing low-cost widespread personalized services such as multiplexed data, speech, video, and intelligent sensor-based systems for personal security. Current prototype systems that have been built include low-power sensor networks and portable computer networking systems for video as well as speech and data services.

Graduate students have an opportunity to perform fundamental research in any of the areas mentioned above while developing a systems viewpoint and obtaining rich experience in the practical art. Industry sponsors can leverage the unique combination of talents in the multiple disciplines that are essential to develop integrated low-cost, low-power wireless systems to address needs in a variety of sectors such as financial information management, personal communications, and educational networks. The facilities for this research group include a test-bed consisting of commercial as well as research prototypes for conducting experiments in wireless communications to develop new ideas for signal processing, modulation, and networking algorithms as well as for integrated circuit architectures and integrated antennas. The group is supported by DARPA and several industries.

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

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

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

* Also Professor of Mathematics

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

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 for signal processing circuits

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

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)
Ultrafast optics and electronics, optoelectronics and semiconductor lasers, nonlinear optics, optical-wave propagation

Warren B. Mori, Ph.D. (UCLA, 1987)
Laser plasma interactions, advanced accelerator concepts, advanced light sources

Dee-Son Pan, Ph.D. (Cal Tech, 1977)
New semiconductor devices for millimeter and submillimeter wave generation and amplification, transport in small geometry semiconductor devices, generic device modeling

*C. Kumar N. Patel, Ph.D. (Stanford, 1961)
Nonlinear optics, opto-acoustic effects and applications, spectroscopy of transplant liquids and solids, medical applications of lasers

* Also Professor of Physics

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

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

Behzad Razavi, Ph.D. (Stanford, 1992)
Analog, RF, and mixed-signal integrated circuit design, dual-standard RF transceivers, phase-locked systems and frequency synthesizers, 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, optical networks, multimedia IP and ATM networks, satellite networks, queueing systems, C3 systems and 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 filtering, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, and fast algorithms for large-scale problems

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

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, MBE and superlattices, microwave and millimeter electronics/optoelectronics, quantum computing

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

Ming C. Wu, Ph.D. (UC Berkeley, 1988)
MEMS, micro-opto-electromechanical systems (MOEMS), optoelectronics, RF photonics, optical communications

Eli Yablonovitch, Ph.D. (Harvard, 1972)
Optoelectronics, high-speed optical communications, photonic integrated circuits, photonic crystals at optical and microwave frequencies, 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)
Plasma processing of semiconductor circuits

Robert S. Elliott, Ph.D. (Illinois, 1952)
Electromagnetics

Richard E. Mortensen, Ph.D. (UC Berkeley, 1966)
Optimal control, stochastic control, nonlinear filtering, estimation theory, guidance and navigation

H.J. Orchard, M.Sc. (U. London, 1951)
Circuit theory, network design, filters, RC-active circuits

Frederick W. Schott, Ph.D. (Stanford, 1949)
Electromagnetics, applied electromagnetics

Gabor C. Temes, Ph.D. (U. 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

William H. Mangione-Smith, Ph.D. (Michigan, 1992)
Computer architecture and microarchitecture design and evaluation, compiler technology for low power and high performance

Fernando G. Paganini, Ph.D. (Cal Tech, 1996)
Robust and optimal control, distributed control, control communication networks, power systems

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Wireless and mobile computing and networking systems, networked and distributed embedded systems, low-power and power-aware systems, system-on-a-chip design tools

Lieven Vandenberghe, Ph.D. (Katholieke U., Leuven, Belgium, 1992)
Optimization in engineering and applications in systems and control, circuit design, and signal processing

† Also Professor Emeritus of Anesthesiology

Ingrid M. Verbauwhede, Ph.D. (Katholieke U., Leuven, Belgium, 1991)
VLSI, architecture design and circuit design and design methodologies for programmable and application-specific integrated circuits (ASICS) and systems on a chip

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

Assistant Professors

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

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

C.-K. Ken Yang, Ph.D. (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design

Adjunct Professors

Nicolaos G. Alexopoulos, Ph.D. (Michigan, 1968)
Integrated microwave and millimeter wave circuits and antennas, substrate materials and thin films, electromagnetic theory

Donald Arnush, Ph.D. (MIT, 1961)
Plasma physics, electromagnetic sources and accelerators, radar, microwave radiometry, space-borne sensors

Giorgio Franceschetti, Ph.D. (Higher Institute of Telecommunications, Rome, 1961)
Electromagnetic radiation and scattering, nonlinear propagation, synthetic aperture radar processing

Paul T. Greiling, Ph.D. (Michigan, 1970)
Solid-state microwave/millimeter wave devices and ICs

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

Neville C. Luhmann, Jr., Ph.D. (Maryland, 1972)
Millimeter wave imaging, gyrotrons, free-electron lasers, plasma

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

Pyotr Y. Ufimtsev, Ph.D. (Central Research Institute, Radio Industry, Moscow, Russia, 1959)
Electromagnetics, diffraction theory, gaseous waveguides, materials

Adjunct Associate Professors

Bijan Houshmand, Ph.D., (Illinois, Urbana, 1990)
Computational electromagnetics, microwave imaging, and remote sensing

Kenneth W. Iliff, Ph.D. (UCLA, 1973)
Aircraft parameter estimation, flight testing, control systems, aircraft dynamics, aerodynamics, parameter/systems identification

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

Robert J. Greenberg, M.D., Ph.D. (Johns Hopkins, 1998)
Electrical stimulation of the retina especially modeling and electrophysiology with goal of creating a retinal prosthesis for patients blind from outer retinal degenerations, such as retinitis pigmentosa

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) (Not the same as course 2 prior to Winter Quarter 1999.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 1. Introduction to modern physics necessary to understand solid-state devices, including elementary quantum theory, Fermi energies, and concept of electrons in solids. Derivation of electrical properties of holes and junctions. Letter grading.
Mr. Fetterman, Mr. Pan (F,W,Sp)

10. Circuit Analysis I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 1 or Physics 1C. Corequisite: Mathematics 33A. 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)

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: course 1 or Physics 1C, 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: course 5C or Computer Science 31 or Civil Engineering 15 or Mechanical and Aerospace Engineering 20, Mathematics 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 10 or 100. 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, three hours; discussion, one hour; outside study, nine hours. Requisites: courses 102, 110. 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,W,Sp)

113L. Digital Signal Processing Laboratory. (2) Laboratory, four hours; outside study, two hours. Requisite: course 113. Recommended: Computer Science M151B. 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. Letter grading. Mr. Jain, Ms. Verbauwhede (F,W,Sp)

114D. Speech and Image Processing Systems Design. (4) (Formerly numbered 114.) 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, three 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: courses 115B, 121A. 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)

116B. VLSI System Design. (4) Lecture, three hours; discussion, one hour; laboratory, four hours; outside study, four hours. Requisites: courses M16, 115C, and 113L or M116D. Familiarity with digital circuit, logic design, and computer architecture assumed. VLSI design from a 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,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 (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)

121A. Physical Principles of Semiconductor Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 2 or Physics 1C, Materials Science 14. Introduction to physics of semiconductors; survey of equilibrium and nonequilibrium electronic processes in semiconductors; principles of operation and design of p-n junction devices. Fabrication of semiconductor devices. Letter grading. Mr. Viswanathan (F,W)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 121A. 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)

122AL. Semiconductor Devices Laboratory. (5) Lecture, four hours; laboratory, four hours; outside study, seven 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. Requisites: courses 121A, 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, 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 HSSEASnet 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)

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 Laboratory. (4) (Formerly numbered 151A.) (Same as Biomedical Engineering M150L and Mechanical and Aerospace Engineering M180L.) Lecture, three hours; laboratory, four hours; outside study, five hours. Requisites: course 1 or Physics 1C, Chemistry 20A. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce a variety of MEMS, including microstructures, microsensors, and microactuators. Students fabricate set of basic MEMS structures in hands-on microfabrication laboratory. Letter grading. Mr. Judy (F)

151DL. Microelectromechanical Systems Design. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Requisites: courses 115A, 115B. Microelectromechanical systems design, combining lecture and laboratory instruction on microsensor and microactuator fundamental operating principles and high-resolution electronic measurement methods for transducers. Emphasis on design of transducers and interface systems using device and system-level tools. Letter grading. Mr. Kaiser (Sp, alternate years)

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. Requisites: courses 121A, 121B. MESFET, HEMT, HBT, IMPATT, Gunn, small signal models, noise model, large signal model, load-pull 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)

164AL. Microwave Wireless Laboratory I. (2) Lecture, one hour; laboratory, three hours; outside study, three hours. Requisite: course 161. Measurement techniques and instrumentation for active and passive microwave components; cavity resonators, waveguides, wavemeters, slotted lines, directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip and coaxial systems. Letter grading. Mr. Itoh, Mr. Jalali (W)

164DL. Microwave Wireless Laboratory II. (2) (Formerly numbered 164BL.) Lecture, one hour; laboratory, two hours; outside study, three hours. Requisite: course 161. Microwave integrated circuit design from a 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)

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) (Formerly numbered 173L.) 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)

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)

190D. Systems Design. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Requisites: courses 113, 132A, 141. 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 (F,Sp)

199. Special Studies. (2 to 8) Tutorial, to be arranged. Limited to seniors. Individual investigation of selected topic to be arranged with a faculty member. Enrollment request forms available in department office. Only 2 units may be applied toward degree; the 2 units must be approved by petition and can be used only as a replacement for a regular electrical engineering laboratory course. Students may take additional 199 courses, but they may not be applied toward degree. 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)

202A. Embedded and Real-Time Systems. (4) Lecture, four hours; outside study, eight hours. Designed for graduate computer science and electrical engineering students. Methodologies and technologies for behavioral synthesis, system synthesis, and real-time issues in embedded systems. Topics include behavioral synthesis, hardware/software codesign, interface synthesis, scheduling, real-time constraints, real-time specification and modeling, transformation and estimations during synthesis and design optimization, concurrency, real-time OS, and embedded processors. Design for low power, verification, and debugging. Letter grading. Mr. Srivastava (F)

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)

206A. Mobile and Wireless Networked Computing Systems. (4) Lecture, four hours; outside study, eight hours. Designed for graduate computer science and electrical engineering students. Interdisciplinary course covering mobile computing, wireless networking, and multimedia processing techniques for computing systems capable of ubiquitous transport and processing of multimedia information. Topics include wireless and cellular fundamentals, network mobility management, low-power portable node architecture, mobile IP, wireless TCP, middleware and operating system issues, and context-aware adaptive applications. Letter grading. Mr. Srivastava (Sp)

M208A. Analytical Methods of Engineering I. (4) (Same as Mechanical and Aerospace Engineering M291A.) Lecture, four hours; outside study, eight hours. Requisites: Mathematics 131A, 132. Application of abstract mathematical methods to engineering problems. Review of elements of measure and integration, L_2 theory — linear spaces and operators. Eigenvalue problems. Introduction to spectral theory — elementary distribution theory. Applications to problems in engineering. Letter grading.
Mr. Balakrishnan (F,W)

M208B. Analytical Methods of Engineering II. (4) (Same as Mechanical and Aerospace Engineering M291B.) Lecture, four hours; outside study, eight hours. Requisite: course M208A or Mechanical and Aerospace Engineering M291A. 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) (Formerly numbered 210.) 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 multiresolution analysis using wavelet transforms. Letter grading. Mr. Villasenor

212A. Theory and Design of Digital Filters. (4) Lecture, three hours; outside study, nine 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) (Formerly numbered 214A.) (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; outside study, eight 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. K.L. Wang (Sp)

M216A. LSI in Computer System Design. (4) (Same as Computer Science M258A.) Lecture, four hours; laboratory, four hours. Limited to graduate computer science and electrical engineering students. 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 and S/U or letter grading. Mr. Jain, Mr. Mangione-Smith

M217. Biomedical Imaging. (4) (Formerly numbered 217.) (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. Requisite: course 121A. 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. Requisite: course 121A. 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. Requisite: course 121A. 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 metalization. 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. Superlattices and Quantum Wells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods for circulating electronics and optical properties of semiconductor quantum wells, superlattices, and tunnel structures. Quantum size effects and low-dimensional systems. Application to semiconductor 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; outside study, eight 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; outside study, eight 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; outside study, eight hours. Requisite: course 131A. Introduction to stochastic processes as applied to study of telecommunication systems and traffic engineering. Renewal theory; discrete-time Markov chains; continuous-time Markov jump processes. Applications to traffic and queueing analysis of basic telecommunication system models. Letter grading.
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)

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) (Formerly numbered 240A.) (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) (Formerly numbered 240C.) (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. Fundamentals and applications of second-order theory stochastic processes. Correlation and spectral density. Gaussian process, processing by dynamic systems, Bayes rule and conditional expectation; mean-square estimation and Kalman filtering. Letter grading. Mr. Balakrishnan (F)

241B. Kalman Filtering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M240A, 241A. Statistical estimation theory, estimation of signal parameters in additive noise. Kalman filter theory: basic theory, steady state and frequency domain analyses, on-line estimation and colored noise. Likelihood ratios, Gaussian signals in Gaussian noise. 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) (Formerly numbered 242.) (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)

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) (Formerly numbered 250A.) (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) (Formerly numbered 250B.) (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)

250C. Microsensors and Microinstruments. (4) Lecture, three hours; laboratory, three hours, outside study, six hours. Requisite: course M250B. Fundamentals of microelectromechanical systems (MEMS) microsensors and microinstruments. Measurement principles for MEMS transducers. Design methods and design constraints for sensitivity and stability. Implementation of control methods for improving measurement sensitivity, linearity, and reproducibility. Design project required, with emphasis on integration of sensors and actuators. Letter grading.
Mr. Judy, Mr. Kaiser (F)

259S. Seminar: Microelectromechanical Systems. (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. Arrayfed 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 173L 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 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)

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., *Vice Chair*
Ya-Hong Xie, Ph.D., *Vice Chair*

Professors

Alan J. Ardell, Ph.D.
Bruce S. Dunn, Ph.D.
Mark S. Goorsky, Ph.D.
Kanji Ono, Ph.D.
King-Ning Tu, 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 Professor

Benjamin Wu, 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 and Objectives

At the heart of materials science is an understanding of the microstructure of solids. “Microstructure” is used broadly in reference to solids viewed at the subatomic (electronic) and atomic levels, and the nature of the defects at these levels. The microstructure of solids at various levels profoundly influences the mechanical, electronic, chemical, and biological properties of solids. The phenomenological and mechanistic relationships between microstructure and the macroscopic properties of solids are, in essence, what materials science is all about.

Materials engineering builds on the foundation of materials science and is concerned with the design, fabrication, and optimal selection of engineering materials that must simultaneously fulfill dimensional, property, quality control, and economic requirements.

The department also has a program in electronic materials that provides a broad-based background in materials science, with opportunity to specialize in the study of those materials used for electronic and optoelectronic applications. The program incorporates several courses in electrical engineering in addition to those in the materials science curriculum.

The undergraduate program leads to the B.S. degree in Materials Engineering. Students are introduced to the basic principles of metallurgy and ceramic and polymer science as part of the department's Materials Engineering major.

A joint major field, Chemistry/Materials Science, is offered to students enrolled in the Department of Chemistry and Biochemistry (College of Letters and Science).

The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

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 88 (2 units), 110, 110L, 120, 130, 131, 131L, 132, 143A, 150, 160, 161L, 190, 191L; Mechanical and Aerospace Engineering 191A or 192A
3. Three elective courses from Chemical Engineering C114, Civil and Environmental Engineering 130, 130F, 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 197, 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 or Mechanical and Aerospace Engineering 20; 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 Curricular Requirements on page 22 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 88, 110, 110L, 120 (or Electrical Engineering 2), 121, 122, 130, 131, 131L, 190; Electrical Engineering 121B, 122AL, 123A, 123B, and two courses from Materials Science and Engineering 132, 150, 160; Mechanical and Aerospace Engineering 191A or 192A
3. Four elective courses from Materials Science and Engineering 111, 143A, 162, Electrical Engineering 110, 124, 131A, 172; two laboratory courses from Materials Science and Engineering 161L, 191L, 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 Curricular Requirements on page 22 for details

Graduate Study

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

The following introductory information is based on the 2002-03 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 which 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, 150, 160, 161L, 190, 191L, 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 for the written and oral preliminary examinations.

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. 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. 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 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. After all coursework is completed in the major and minor fields, students take a written preliminary examination in the major field. 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.

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
- Nondestructive Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Glass and Ceramics Research Laboratories
- X-Ray Diffraction Laboratory
- Thin Film Deposition Laboratory
- Mechanical Testing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Electron Microscopy Laboratories with a scanning transmission electron microscope (100 KV) and a scanning electron microscope, both equipped with a full quantitative analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes

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

Bruce S. Dunn, Ph.D. (UCLA, 1974)
Solid electrolytes, electrical properties of ceramics and glasses, ceramic-metal bonding, optical materials

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

Kanji Ono, Ph.D. (Northwestern, 1964)
Mechanical behavior and nondestructive testing of structural materials, acoustic emission, dislocations and strengthening mechanisms, microstructural effects, and ultrasonics

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

Ya-Hong Xie, Ph.D. (UCLA, 1986)
Cross-talk isolation in Si RF-digital mixed signal integrated circuits, SiGels, hetero-epitaxial structures, self-assembled quantum dot arrays, and other Si-based novel device structures

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 Professor

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. (U. 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

Students in Professor Dunn's laboratory investigating the preparation and properties of materials

Lower Division Courses

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)

88. Freshman Seminar: New Materials. (2) 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)

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)

Upper Division Courses

110. Introduction to Materials Characterization A (Crystal Structure and X-Ray Diffraction of Material). (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)

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)

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)

CM180. Introduction to Biomaterials. (4) (Formerly numbered M180.) (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)

190. Materials Selection and Engineering Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 132, 150, 160. Explicit guidance among the 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)

191L. Computer Methods and Instrumentation in Materials Science. (2) Lecture, two hours; outside study, 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)

197. Seminar: Technical Writing for Materials Engineers. (2) Seminar, two hours; outside study, four hours. Corequisite: course 132 or 190 or 598 or 599. Types of technical documents and basic document patterns. Document planning, paragraph and sentence structures. Illustration and references. Reports, theses, and proposals. Oral presentation. Letter grading. (Sp)

199. Special Studies. (2 to 8) Tutorial, to be arranged. Limited to seniors. Individual investigation of selected topic to be arranged with a faculty member. Enrollment request forms available in department office. Occasional field trips may be arranged. May be repeated for credit. 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)

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 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)

474A. Advanced Transportation Systems. (4) Lecture, four hours; outside study, eight hours. Survey of aerospace and advanced ground transportation systems, materials, structures, propulsion systems, control systems, communication systems, and infrastructure support. Letter grading.

475A. Manufacturing Processes. (4) Lecture, four hours; outside study, eight hours. Manufacturing properties of materials, thermomechanical processes, chemical and physical processes, material removal processes, packaging, fastening, joining and assembly, tooling and fixtures. Letter grading.

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

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

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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http://www.mae.ucla.edu/

H. Thomas Hahn, Ph.D., *Chair*
Nasr M. Ghoniem, Ph.D. , *Vice Chair*
Tsu-Chin Tsao, Ph.D., *Vice Chair*

Professors

Mohamed A. Abdou, Ph.D.
Satya N. Atluri, Ph.D.
Oddvar O. Bendiksen, Ph.D.
Gregory P. Carman, Ph.D.
Albert Carnesale, Ph.D., *Chancellor*
Ivan Catton, Ph.D.
Vijay K. Dhir, Ph.D., *Interim Dean*
Rajit Gadh, Ph.D.
Nasr M. Ghoniem, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
H. Thomas Hahn, Ph.D. *(Hughes Aircraft 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.
Robert E. Kelly, Sc.D.
Chang-Jin (C-J) Kim, Ph.D.
J. John Kim, Ph.D. *(Rockwell International Professor of Engineering)*
Adrienne G. Lavine, Ph.D.
Ajit K. Mal, Ph.D.
William C. Meecham, Ph.D.
Anthony F. Mills, Ph.D.
D. Lewis Mingori, 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

Harry Buchberg, M.S.
Andrew F. Charwat, Ph.D.
Peretz P. Friedmann, Sc.D.
Walter C. Hurty, M.S.
Cornelius T. Leondes, Ph.D.
Michel A. Melkanoff, 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.
William T. Thomson, Ph.D.
Russell A. Westmann, Ph.D.

Associate Professors

Robert T. M'Closkey, Ph.D.
Xiang Zhang, Ph.D.

Senior Lecturer

Alexander Samson, Ph.D., *Emeritus*

Lecturers

Ravnesh Amar, Ph.D.
C.H. Chang, M.S., *Emeritus*
Rudolf X. Meyer, Dr.Engr.

Adjunct Professors

Leslie M. Lackman, Ph.D.
Neil B. Morley, Ph.D.

Scope and Objectives

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.

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. Ten department core courses: Civil and Environmental Engineering 108, Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 20, 102, 103, M105A, 105D, 157, 192A
2. Twelve aerospace engineering core courses: Electrical Engineering 102, 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 191A, 192B, 192C, Electrical Engineering 103, 131A
3. Sixteen technical elective units (which should contain enough design units to satisfy the overall pro-

gram 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 156B, 166C, 168, 193, Civil and Environmental Engineering 130F (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 Curricular Requirements on page 22 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. Ten department core courses: Civil and Environmental Engineering 108, Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 20, 102, 103, M105A, 105D, 157, 192A
2. Eleven mechanical engineering core courses: Electrical Engineering 110L, Mechanical and Aerospace Engineering 94, 131A, 133A, 156A, 162A, 162B, 162M, 169A, 171A, 193
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; laboratory courses: Mechanical and Aerospace Engineering 162C, 172, M180L, 194, 195
   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, 156B, 163A, 168, 171B, 174, 191A; laboratory courses: Civil and Environmental Engineering 130F, 137L, Mechanical and Aerospace Engineering 172
   c. *Fluids and Thermal Engineering:* Electrical Engineering 103, Mechanical and Aerospace Engineering 132A, 134, 136, 150A, 150B, 150C, 150P, 150R, 153A, 161A, 161B, 174, 192B, 192C; 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 Curricular Requirements on page 22 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

Graduate Study

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

The following introductory information is based on the 2002-03 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, 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, 150, 160, 161L, 190, 191L, 199; Mechanical and Aerospace Engineering 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 250D, 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 four categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A or 156B.

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, which is offered every quarter, must be in written form. The comprehensive examining committee may conduct an oral examination after review of the written examination. Students may, in consultation with the adviser and the major field chair, elect to take the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination. 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, 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, 150, 160, 161L, 190, 191L, 199; Mechanical and Aerospace Engineering 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, 193, 194, 195.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, M280, 293, 294, 295, 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 226B, M227B, 227D; Computer Science 241A, 241B; Management 240A, 240B, 240C, 240D, 241A, 241B, 242A, 242B, 243A, 243B, 243C; Mathematics 120A, 120B.

Comprehensive Examination Plan

The comprehensive examination, which is offered every quarter, must be in written form. The comprehensive examining committee may conduct an oral examination after review of the written examination. 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 *Composites Laboratory* is used for manufacturing and testing of composite structures and products, which include polymer matrix composites, metal matrix composites, and electromagnetically coupled material systems. Housed in this laboratory are an autoclave, filament winder, injection molding machine, smart press, resin transfer molding machine, walk-in freezer, long-distance microscope, and Moiré interferometer.
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 *Design and Manufacturing Engineering Laboratory* provides an environment for synergistic integration of design and manufacturing. The equipment available includes four computer numerically controlled (CNC) machines, two rapid prototyping machines, coordinate measuring machine, X-ray radiography machine, actuation devices, robots with vision systems, a variety of audiovisual equipment, and a distributed network of more than 30 workstations and several personal computers.
10. The *Integrated Manufacturing Engineering Laboratory* is used for manufacturing and testing of composites structures and products, which include polymer matrix composites, metal matrix composites, and electromagnetically coupled material systems. The laboratory houses an autoclave, filament winder, injection molding machine, smart press, resin transfer molding machine, walk-in freezer, long-distance microscope, Moiré interferometer, three mechanical testing machines, and equipment for characterization and testing of electromagneto-thermo materials and structures.
11. The *Computational Fluid Dynamics Laboratory* includes a cluster of graphic workstations and X-terminals for numerical simulation of transitional and turbulent flows with and without reaction. The laboratory has access to supercomputers at NASA, San Diego Supercomputing Center, and the DoD High-Performance Computing Centers.
12. 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.

Student project leaders Brian Posner and Avi Okon display the inner workings of the ASME combat robot, the Boelter Beast. The robot group competes annually in a televised national competition.

13. 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.

14. 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.

15. The *Microsciences Laboratory* is equipped with advanced sensors and imaging processors for exploring fundamental physical mechanisms in MEMS-based sciences.

16. 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.

17. 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

Satya N. Atluri, Ph.D. (MIT, 1969)
Nonlinear continuum, fracture and computational mechanics, engineered materials, structural integrity and damage tolerance, life-cycle cost minimization

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

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)
Composites design and manufacturing, concurrent engineering, rapid prototyping, automation, mechanical behavior, nondestructive evaluation, smart structures

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

Robert E. Kelly, Sc.D. (MIT, 1964)
Thermal convection, thermocapillary convection, stability of shear flows, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics

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 and computational fluid dynamics, numerical simulation of turbulent and transitional flows, turbulence and heat transfer control, control of transition to turbulence, numerical methods for direct and large-eddy simulations

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

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

William C. Meecham, Ph.D. (Michigan, 1954)
Turbulence theory, aircraft noise, community noise

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

D. Lewis Mingori, Ph.D. (Stanford, 1966)
Dynamics and control, stability theory, nonlinear methods, applications to space and ground vehicles

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

Harry Buchberg, M.S. (UCLA, 1954)
Heat transfer processes in energy conversion, conservation and environmental control with emphasis on solar energy use and indoor "climate"

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

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

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 Polytechnic Institute, 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

William T. Thomson, Ph.D. (UC Berkeley, 1938)
Resonant nonlinear control circuits

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 Professors

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

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.

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

Rudolf X. Meyer, Dr.Engr. (Johns Hopkins, 1955)
Space technology

Adjunct Professors

Leslie M. Lackman, Ph.D. (UC Berkeley, 1967)
Structural analysis and design, composite structures

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

Lower Division Courses

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)

20. FORTRAN Programming with Numerical Methods Applications. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Mathematics 31A, 31B. Introduction to programming with FORTRAN. Applications to numerical methods used in engineering; concepts of probability and statistics. 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)

Upper Division Courses

102. Mechanics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A, Physics 1A. Newtonian mechanics (statics and dynamics) of particles and rigid bodies. Fundamental concepts of mechanics. Statics, kinematics, and kinetics of particles and rigid bodies. Impulse/momentum and work/energy relationships. Applications. Letter grading.
Mr. Mingori (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. Kelly (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. Dhir (F,W,Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103, M105A, Mathematics 32B, 33A. Transport phenomena; heat conduction, mass species diffusion, convective heat and mass transfer, and radiation. Engineering applications in thermal and environmental control. Letter grading. Ms. Lavine (F,W,Sp)

131A. Intermediate Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 20, 105D, 192A. 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. Mr. Catton (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 (F, 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 (W, 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. Dhir (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)

136. Thermal Hydraulic Design of Nuclear and Other Power Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for seniors. Thermal hydraulic design of nuclear and other power systems, power generation and heat removal, power cycle, thermal hydraulic component design, overall plant design, steady state and transient operation. Letter grading. Mr. Dhir (W)

CM140. Introduction to Biomechanics. (4) (Formerly numbered M140.) (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, 192A. 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. Kelly (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 (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 (Sp)

153A. Engineering Acoumstics. (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. Meecham (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. Mingori (F)

156A. Strength of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 192A, Civil Engineering 108. 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)

156B. Introduction to Elasticity. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 156A, 192A. Kinematics of deformation, strain displacement relations. Balance laws, stress tensor, principal stresses, equilibrium equations. Conservation of energy, strain energy function. Generalized Hook's law, thermoplasticity and viscoelasticity. Stress calculation in cylinders and spheres. Plane elasticity, Airy's stress function. Stress concentration problems at holes, corners, and crack tips. Letter grading. Mr. Mal (W, alternate years)

157. Basic Mechanical Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 103, M105A, 105D, Civil Engineering 108, 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. Ho (Sp)

161A. Introduction to Astronautics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102. Recommended: course 192A. 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. Mingori (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. Mingori (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. Dhir (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, Mr. Yang (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: Civil Engineering 108. 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. Atluri (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: course 20, Civil Engineering 108, Mathematics 33A. Recommended: courses 94 or 194, 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. Atluri, Mr. Carman (Sp)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102, 192A, 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 191A or 192A 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. Dhir (F)

M180L. Introduction to Micromachining and Microelectromechanical Systems Laboratory. (4) (Formerly numbered 180.) (Same as Biomedical Engineering M150L and Electrical Engineering M150L.) Lecture, three hours; laboratory, four hours; outside study, five hours. Requisites: Electrical Engineering 1 or Physics 1C, Chemistry 20A. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce a variety of MEMS, including microstructures, microsensors, and microactuators. Students fabricate set of basic MEMS structures in hands-on microfabrication laboratory. Letter grading. Mr. C-J. Kim (F)

191A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 192A. 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)

192A. Mathematics of Engineering. (4) 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. Dhir (F,W,Sp)

192B. Mathematics of Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 192A. 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. Kelly (Sp)

192C. Numerical Methods for Engineering Applications. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 20, 192A. 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)

193. Introduction to Manufacturing Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: Materials Science 14. Mechanical behavior of materials. Manufacturing properties of metals. Surfaces of materials. Metal cutting, deformation processes, and casting. Joining and fastening. Nonconventional material-removal processes. Polymers, ceramics, and composites. Letter grading.
Mr. Hahn, Mr. C-J. Kim (F,Sp)

194. Introduction to Geometry Modeling. (4) 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)

195. Computer Numerical Control and Applications. (4) 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. Chang (Sp)

199. Special Studies. (2 to 8) Tutorial, to be arranged. Limited to seniors. Individual investigation of selected topic to be arranged with a faculty member. Enrollment request forms available in department office. Occasional field trips may be arranged. May be repeated for credit. Letter grading. (F,W,Sp)

Graduate Courses

231A. Convective Heat Transfer Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 192B. 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. Chen (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. Dhir (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

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. Dhir (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. Chen (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

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. Dhir

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. (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 (F, 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 192B. 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. Kelly, 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.
Mr. J. Kim, Mr. Meecham (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, 192C. 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 192A, 192B, 192C, 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)

251A. Stratified and Rotating Fluids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Fundamentals of fluid flows with density variations or rotation, illustrated by examples with environmental, geophysical, or technical importance. Linear and finite amplitude wave motion. Flow past bodies; blocking phenomena. Viscous effects. Instabilities. Turbulent shear flows, wakes, plumes, and gravity currents. Letter grading.
Mr. Kelly (F, even years)

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. Kelly (W, odd years)

252B. Statistical Theory of Turbulence. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Development of statistical methods of wide utility in engineering applied to turbulent flows. Topics include stochastic processes, kinematics of turbulence, energy decay. Kolmogorov similarity, analytical theories, and origins of Reynolds stress. Letter grading. Mr. Meecham (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. Meecham

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. Meecham

254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 192A, 192B, 192C. 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. Mingori (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. Mingori (Sp, odd years)

M256A. Mechanics of Deformable Solids. (4) (Formerly numbered 256A.) (Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A. Kinematics of deformation, strain, tensors, invariance, compatibility; conservation laws; stress tensors; equations of motion; boundary conditions; constitutive equations: general theory, linearization, anisotropy; reciprocity linear isotropic elastic problems, plane and generalized plane problems; dynamic problems. Letter grading.
Mr. Mal (F)

M256B. Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Equations of linear elasticity; uniqueness of solution; Betti/Rayleigh reciprocity; Saint-Venant's principle; simple problems involving spheres and cylinders; special techniques for plane problems. Airy's stress function, complex variable method, transform method; three-dimensional problems, torsion, entire space and half-space problems; boundary integral equations. 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. Atluri (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. Kelly (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 Variational Principles in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 156B or 166A. Theory of linear elasticity. Calculus of variations. Principles of minimum potential energy and complementary energy. Stationary variational principles. Energy theorems. Matrix methods of structural analysis, with application to truss and frame problems. Variational principles as basis of finite element methods. Letter grading. Mr. Bendiksen (F)

261B. Methods of Computational Mechanics I. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 168, 261A. Weighted residual methods, weak forms, local trial and test functions, primal finite element method, multifield finite elements, high-performance elements and avoidance of locking, integral equation and field boundary element methods, finite volume methods, meshless methods, term projects using digital computers. Applications to aerospace and mechanical engineering structural and solid mechanics, incompressible fluid flow, and heat transfer. Letter grading. Mr. Atluri (W)

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156B. Recommended: 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. Mingori (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. Shiller (Sp)

M267A. Optimum Structural Design. (4) (Same as Civil Engineering M240.) Lecture, four hours; outside study, eight hours. Requisite: course 261A or Civil Engineering 235A. Synthesis of structural systems; analysis and design as optimization problems; techniques for synthesis and optimization; application to aerospace and civil structures. Letter grading. Mr. Bendiksen, Mr. Felton (W)

268B. Failure of Structural Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: Civil Engineering 135B. Exploration of a current area of research in depth. Letter grading. Mr. Atluri

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) (Formerly numbered 270A.) (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) (Formerly numbered 270C.) (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. Speter (W)

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. (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) (Formerly numbered 280.) (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)

286. Molecular Dynamics Simulation. (4) (Formerly numbered 282.) Lecture, four hours; outside study, eight hours. Preparation: computer programming experience. Requisites: courses 192A, 192C. 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. Hahn (W)

287. Advanced Microelectromechanical Systems (MEMS). (4) Lecture, four hours; outside study, eight hours. Requisite: course M280 or Electrical Engineering M250A. Silicon micromachining, nonsilicon micromachining, nonlithographic processes. Mechanical issues of MEMS structures. Driving mechanisms for microactuators, including electrostatic, electromagnetic, thermal, and fluidic actuation. Applications to mechanical and aerospace areas. Studies of MEMS products and state-of-the-art research. Letter grading. Mr. C-J. Kim (F, alternate years)

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)

M291A. Analytical Methods of Engineering I. (4) (Same as Electrical Engineering M208A.) Lecture, four hours; outside study, eight hours. Requisites: Mathematics 131A, 132. Application of abstract mathematical methods to engineering problems. Review of elements of measure and integration, L_2 theory — linear spaces and operators. Eigenvalue problems. Introduction to spectral theory — elementary distribution theory. Applications to problems in engineering. Letter grading. Mr.Gibson (F,W)

M291B. Analytical Methods of Engineering II. (4) (Same as Electrical Engineering M208B.) Lecture, four hours; outside study, eight hours. Requisite: course M291A or Electrical Engineering M208A. 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. Gibson (W,Sp)

291C. Integral Equations in Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: Mathematics 250B. Introduction to generalized function theory and Green's functions. Conversion of partial equations to integral equations and classification of integral equations. Solution to integral equations with degenerate kernels; discussions of successive approximations and Fredholm and Hilbert/Schmidt theory. Letter grading. Mr. Mal

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)

295. Computer-Aided Manufacturing. (4) Lecture, four hours; outside study, eight hours. Preparation: one course from 163A, 163C, 195. 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)

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 132A, 193. 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 (W)

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

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.

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.
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 and S/U or letter 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.
Herbert B. Nottage, 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

Herbert B. Nottage, Ph.D. (Case Institute of Technology, 1952)
Engineering design; biotechnology; pollution control; energy conservation, conversion, and heat and mass transfer and fluid flow processes; instrumentation; industrial engineering and automation, especially fluidics; vehicles, engines, and turbomachinery; air-conditioning and refrigeration; inhabited environments; waste processing and reclamation; mathematical analysis of systems, cost-benefit economics

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

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)

97. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as a professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through the 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)

Upper Division Courses

194. Power and Ethics in Engineering History. (4) Lecture, two hours; discussion, one hour; outside study, seven hours. Limited to juniors/seniors. Rigorous framework for analyzing social constraints to technological change and use of ethical, economic, and historical frameworks, with emphasis on scientific, industrial, and military perspectives. Designed for engineering and computer science students as a humanities class for investigating strategic relationships among social power, moral responsibility, and technological change. Letter grading. Mr. Jacobsen (F)

195. Art of Engineering Endeavors. (4) (Formerly numbered 98.) 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)

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

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)

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)/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 grading (course 471A); In Progress and S/U or letter grading (courses 471B, 471C).

472A-472D. The Engineer in the Business Environment. (3-3-3-1.5) Lecture, three hours (courses 472A, 472B, 472C)/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 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 and S/U 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.

Henry Samueli School of Engineering and Applied Science Affiliated Faculty Members

Christopher W. Grose, Ph.D., *Professor Emeritus of English, UCLA*

George Grüner, Ph.D., *Professor of Physics, UCLA*

James V. Ralston, Jr., Ph.D., *Professor of Mathematics, UCLA*

Howard Reiss, Ph.D., *Professor Emeritus of Chemistry and Biochemistry, UCLA*

Robert G. Rinker, Ph.D., *Professor Emeritus of Chemical Engineering, UC Santa Barbara*

Steven E. Schwarz, Ph.D., *Professor Emeritus of Electrical Engineering and Computer Sciences, UC Berkeley*

Robin Shepherd, Ph.D., D.Sc., *Professor Emeritus of Civil and Environmental Engineering, UC Irvine*

Research Centers, Laboratories, and Institutes

Artificial Intelligence Laboratory

Michael G. Dyer (Computer Science), *Director*

The Artificial Intelligence (AI) Laboratory was established in 1984 to support graduate research and education in the following areas:

Natural language processing (NLP). Computer comprehension and generation of text (e.g., short stories, editorials, and dialogs). Related tasks include question answering, paraphrasing, and machine translation of natural language texts.

Cognitive modeling. Simulation of high-level cognitive functions, including representation of thought, machine learning, creativity and invention, planning and goal analysis, role of emotion in high-level cognition, modeling of human memory, argumentation and belief analysis, moral judgment and legal reasoning, naive physics, humor (e.g., irony), and abstract theme analysis.

Application of artificial neural network technology to modeling high-level cognitive tasks. Mechanisms include parallel distributed processing (PDP) approaches, tensor networks, self-organizing feature maps, recurrent backpropagation, localist spreading activation networks, and hybrid symbolic/neural models. Tasks include NLP, language acquisition, and "symbol grounding" (i.e., relating language to perceptual information).

Evolution of language and communication. Use of genetic algorithms (i.e., mutation and recombination of artificial genomes) to evolve populations of artificial neural networks that communicate and cooperate to accomplish survival-based tasks, such as mate-finding, food gathering, and nest construction.

Other AI faculty members within the Computer Science Department direct research in the areas of heuristic search and distributed AI, game playing, decision-making and Bayesian networks, neural modeling, machine vision, and expert systems.

Center for Environmental Risk Reduction and Pollution Prevention

Yoram Cohen (Chemical Engineering), *Director;* http://www.cerr.ucla.edu/

The Center for Environmental Risk Reduction (CERR) is a multidisciplinary research center established in 1995. The objective of the CERR is to develop and evaluate risk reduction and pollution prevention technologies and strategies. The CERR focuses its research activities in a number of key areas such as

1. Multimedia studies of the transport, exposure, and health risks associated with environmental contaminants. Fundamental research is stressed, with emphasis on transport process modeling, biochemical transformation, exposure modeling and monitoring,
2. Development of clean ("green") processes as substitute for current processes that utilize toxic chemicals or lead to emission of toxics, and
3. Evaluation and development of strategies and technologies for risk reduction and pollution prevention, including recovery and recycle of trace-level contaminant, product and raw material substitution, and policy-driven strategies

The CERR includes student and faculty members from HSSEAS.

Center for High-Frequency Electronics

See Electrical Engineering Department

Flight Systems Research Center

A.V. Balakrishnan (Electrical Engineering), *Director;* Kenneth W. Iliff (Electrical Engineering), *Associate 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 Atmospheric Sciences, Computer Science, Electrical Engineering, Mathematics, and Mechanical and Aerospace Engineering Departments are currently associated with the center. Current research projects include:

- Estimation of wind profiles from laser-beam propagation distortion
- Probabilistic risk assessment and management
- Modeling of high mach number flows for Pegasus
- Leading-edge cooling
- Modeling, identification, and control with applications to flight vehicles
- Aerothermoelasticity and aeroservoelasticity of a generic hypersonic vehicle
- Vortex modeling of fuel jets in supersonic crossflow
- Instability of liquid fuel jets in high-speed flows
- Fluid flow and heat convection studies for actively cooled airframes
- Imaging of gas jets injected into transonic and supersonic crossflows

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.

Nanoelectronics Research Facility

See Electrical Engineering Department

B.S. in Aerospace 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Mathematics 31B — Calculus and Analytic Geometry	4
Mechanical and Aerospace Engineering 20 — FORTRAN Programming with Numerical Methods Applications	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
3rd Quarter	
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory	7
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	
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*	4
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*	4
3rd Quarter	
Mathematics 33B — Infinite Series and 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*	4
JUNIOR YEAR	
1st Quarter	
Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids	4
Electrical Engineering 100 — Electrical and Electronic Circuits	4
Mechanical and Aerospace Engineering 105D — Transport Phenomena	4
Mechanical and Aerospace Engineering 192A — Mathematics of Engineering	4
2nd Quarter	
Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics	4
Mechanical and Aerospace Engineering 157 — Basic Mechanical Engineering Laboratory	4
Mechanical and Aerospace Engineering 169A — Introduction to Mechanical Vibrations† or Aerospace Engineering Elective‡	4
HSSEAS GE Elective*	4
3rd Quarter	
Electrical Engineering 102 — Systems and Signals	4
Mechanical and Aerospace Engineering 150B — Aerodynamics	4
Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems	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 Aerospace Engineering Elective‡	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*	4
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 22 for details).

†Either Mechanical and Aerospace Engineering 161A or 169A is required.

‡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 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B — Chemical Energetics and Change	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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 — Introduction to Chemical Engineering	4
Chemistry and Biochemistry 30AL — General Chemistry Laboratory	3
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	6
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)	4
Mathematics 33A — Linear Algebra and Applications	4
3rd Quarter	
Chemistry and Biochemistry 171 — Intermediate Inorganic Chemistry	4
Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids	4
Mathematics 33B — Infinite Series and Differential Equations	4
HSSEAS GE Elective*	4
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A — Momentum Transfer	4
Chemical Engineering 109 — Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics	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 Elective†	4
HSSEAS GE 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*	4
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	**196**

*See page 22 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B — Chemical Energetics and Change	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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 — Introduction to Chemical Engineering	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	6
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)	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 — Infinite Series and 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*	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*	4
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 Electives (2)*	8
TOTAL	**202 or 203**

*See page 22 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 Molecular, Cell, and Developmental Biology or Microbiology, Immunology, and Molecular Genetics or Organismic Biology, Ecology, or Evolution, 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B — Chemical Energetics and Change	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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 — Introduction to Chemical Engineering	4
Chemistry and Biochemistry 30AL — General Chemistry Laboratory	3
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	6
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)	4
Life Sciences 1 — Evolution, Ecology, and Biodiversity	4
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 — Infinite Series and 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*	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*	4
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 Electives (2)*	8
TOTAL	**200 or 201**

*See page 22 for details.
†Biology elective is selected from any upper division course in Molecular, Cell, and Developmental Biology or Microbiology, Immunology, and Molecular Genetics or Organismic Biology, Ecology, and Evolution, 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B — Chemical Energetics and Change	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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 — Introduction to Chemical Engineering	4
Chemistry and Biochemistry 30AL — General Chemistry Laboratory	3
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	6
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)	4
Mathematics 33A — Linear Algebra and Applications	4
3rd Quarter	
Chemistry and Biochemistry 171 — Intermediate Inorganic Chemistry	4
Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids	4
Mathematics 33B — Infinite Series and Differential Equations	4
HSSEAS GE Elective*	4
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A — Momentum Transfer	4
Chemical Engineering 109 — Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics	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 Elective†/Atmospheric Sciences 104 — Fundamentals of Air and Water Pollution	8
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*	4
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‡	4
HSSEAS GE Elective*	4
3rd Quarter	
Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis	4
Environmental Engineering Elective‡	4
Chemistry Elective†/HSSEAS GE Elective*	8
TOTAL	**200**

*See page 22 for details.
†Suggested advanced chemistry electives in the environmental field are Atmospheric Sciences M203A, Chemistry and Biochemistry 103, 110B, Environmental Health Sciences 240, 261, and Organismic Biology, Ecology, and Evolution M127. 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B — Chemical Energetics and Change	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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 — Introduction to Chemical Engineering	4
Chemistry and Biochemistry 30AL — General Chemistry Laboratory	3
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	6
Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)	4
Mathematics 33A — Linear Algebra and Applications	4
3rd Quarter	
Chemistry and Biochemistry 171 — Intermediate Inorganic Chemistry	4
Materials Science and Engineering 14 — Science of Engineering Materials	4
Mathematics 33B — Infinite Series and Differential Equations	4
HSSEAS GE Elective*	4
JUNIOR YEAR	
1st Quarter	
Chemical Engineering 101A — Momentum Transfer	4
Chemical Engineering 109 — Mathematical Methods in Chemical Engineering	4
Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics	4
Electrical Engineering 100 — Electrical and Electronic Circuits	4
2nd Quarter	
Chemical Engineering 101B — Heat Transfer	4
Chemical Engineering 102 — Chemical Engineering Thermodynamics	4
Materials Science and Engineering 120 — Physics of Materials	4
HSSEAS GE 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*	4
SENIOR YEAR	
1st Quarter	
Chemical Engineering 106 — Chemical Reaction Engineering	4
Electrical Engineering 2 — Physics for Electrical Engineers	4
Chemistry Elective†/Semiconductor Manufacturing Engineering Elective‡	8
2nd Quarter	
Chemical Engineering 104C — Semiconductor Processing Laboratory	6
Chemical Engineering 107 — Process Dynamics and Control	4
Chemical Engineering 108A — Process Economics and Analysis	4
HSSEAS GE Elective*	4
3rd Quarter	
Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis	4
Semiconductor Manufacturing Engineering Elective‡	4
Chemistry Elective†/HSSEAS GE Elective*	8
TOTAL	**200**

*See page 22 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 — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B — Calculus and Analytic Geometry	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*	4
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
Mathematics 33A — Linear Algebra and Applications	4
Mechanical and Aerospace Engineering 102 — Mechanics of Particles and Rigid Bodies	4
HSSEAS GE Elective*	4
3rd Quarter	
Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids	4
Mathematics 33B — Infinite Series and Differential Equations	4
Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics	4
HSSEAS GE Elective*	4
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 153 — Introduction to Environmental Engineering Science	4
Mechanical and Aerospace Engineering M105A — Introduction to Engineering Thermodynamics	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
Electrical Engineering 100 — Electrical and Electronic Circuits	4
3rd Quarter	
Electrical Engineering 103 — Applied Numerical Computing	4
Engineering Mathematics Elective	4
Major Field Electives (2)†	8
SENIOR YEAR	
1st Quarter	
Major Field Electives (2)†	8
HSSEAS GE Electives (2)*	8
2nd Quarter	
Major Field Electives (2)†	8
HSSEAS GE Elective*	4
3rd Quarter	
Major Field Electives (2)†	8
HSSEAS GE Elective*	4
TOTAL	**181**

*See page 22 for details.

†At least one major field elective must include a major design project (selected from Civil and Environmental Engineering 135L, 144, 147, 157A, 157B, 157C), and at least 8 units of laboratory 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 — Calculus and Analytic Geometry	4
HSSEAS GE Elective*	4
2nd Quarter	
Computer Science 32 — Introduction to Computer Science II	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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
Electrical Engineering 1 — Electrical Engineering Physics I	4
Mathematics 32B — Calculus of Several Variables	4
HSSEAS GE Elective*	4
2nd Quarter	
Mathematics 33A — Linear Algebra and Applications	4
Mathematics 61 — Introduction to Discrete Structures	4
Physics 4BL — Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	4
3rd Quarter	
Computer Science M152A or Electrical Engineering M116L — Introductory Digital Design Laboratory	2
Electrical Engineering 2 — Physics for Electrical Engineers	4
Mathematics 33B — Infinite Series and Differential Equations	4
HSSEAS GE Elective*	4
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
HSSEAS GE 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
HSSEAS GE Elective*	4
2nd Quarter	
Computer Science 132 — Compiler Construction	4
Computer Science Elective	4
Minor #2	4
3rd Quarter	
Computer Science Elective	4
Minor #3	4
HSSEAS GE Elective*	4
TOTAL	**182**

*See page 22 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.

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 — Calculus and Analytic Geometry	4
2nd Quarter	
Computer Science 32 — Introduction to Computer Science II	4
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
HSSEAS GE Elective*	4
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
Electrical Engineering 1 — Electrical Engineering Physics I	4
Mathematics 32B — Calculus of Several Variables	4
HSSEAS GE Elective*	4
2nd Quarter	
Mathematics 33A — Linear Algebra and Applications	4
Mathematics 61 — Introduction to Discrete Structures	4
Physics 4BL — Electricity and Magnetism Laboratory	2
HSSEAS GE Electives*	4
3rd Quarter	
Computer Science M152A or Electrical Engineering M116L — Introductory Digital Design Laboratory	2
Electrical Engineering 2 — Physics for Electrical Engineers	4
Electrical Engineering 10 — Circuit Analysis I	4
Mathematics 33B — Infinite Series and Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Computer Science M151B or Electrical Engineering M116C — Computer Systems Architecture	4
Electrical Engineering 102 — Systems and Signals	4
Electrical Engineering 110 — Circuit Analysis II	4
Electrical Engineering 110L — Circuit Measurements Laboratory	2
2nd Quarter	
Computer Science 131 — Programming Languages	4
Computer Science 180 — Introduction to Algorithms and Complexity	4
Electrical Engineering 115A — Analog Electronic Circuits I	4
HSSEAS GE Elective*	4
3rd Quarter	
Computer Science 111 — Operating Systems Principles	4
Electrical Engineering 103 — Applied Numerical Computing	4
Electrical Engineering 115AL — Analog Electronics Laboratory I	2
Electrical Engineering 115C — Digital Electronic Circuits	4
Statistics 110A — Applied Statistics	4
SENIOR YEAR	
1st Quarter	
Computer Science 118 — Computer Network Fundamentals	4
Computer Science M152B or Electrical Engineering M116D — Digital Design Project Laboratory	4
Computer Science 181 — Introduction to Formal Languages and Automata Theory	4
Computer Science/Electrical Engineering Elective	4
2nd Quarter	
Computer Science Elective	4
Computer Science Elective	4
Computer Science Elective	4
HSSEAS GE Elective*	4
3rd Quarter	
Computer Science Elective	4
HSSEAS GE Elective*	4
HSSEAS GE Elective*	4
TOTAL	**186**

*See page 22 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.

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 — Calculus and Analytic Geometry	4
HSSEAS GE Elective*	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 — Calculus and Analytic Geometry	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*	4
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*	4
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)*	8
3rd Quarter	
Electrical Engineering 2 — Physics for Electrical Engineers	4
Electrical Engineering 10 — Circuit Analysis I	4
Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems	4
Mathematics 33B — Infinite Series and Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 101 — Engineering Electromagnetics	4
Electrical Engineering 102 — Systems and Signals	4
Electrical Engineering 103 — Applied Numerical Computing	4
Electrical Engineering 110 — Circuit Analysis II	4
Electrical Engineering 110L — Circuit Measurements Laboratory	2
2nd Quarter	
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
Electrical Engineering Elective	4
3rd Quarter	
Electrical Engineering 115A — Analog Electronic Circuits I	4
Electrical Engineering 161 — Electromagnetic Waves	4
Mechanical and Aerospace Engineering 192A — Mathematics of Engineering	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**

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*See page 22 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.
†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 — Calculus and Analytic Geometry	4
HSSEAS GE Elective*	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
3rd Quarter	
Life Sciences 1 — Evolution, Ecology, and Biodiversity	4
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 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*	4
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)*	8
3rd Quarter	
Electrical Engineering 2 — Physics for Electrical Engineers	4
Electrical Engineering 10 — Circuit Analysis I	4
Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems	4
Mathematics 33B — Infinite Series and Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 101 — Engineering Electromagnetics	4
Electrical Engineering 102 — Systems and Signals	4
Electrical Engineering 103 — Applied Numerical Computing	4
Electrical Engineering 110 — Circuit Analysis II	4
Electrical Engineering 110L — Circuit Measurements Laboratory	2
2nd Quarter	
Electrical Engineering 121B — Principles of Semiconductor Device Design	4
Life Sciences 3 — Introduction to Molecular Biology	5
Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)	4
Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics	4
3rd Quarter	
Electrical Engineering 113 — Digital Signal Processing	4
Mechanical and Aerospace Engineering M105A — Introduction to Engineering Thermodynamics	4
Mechanical and Aerospace Engineering 192A — 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	
Electrical Engineering 114D — Speech and Image Processing Systems Design	4
Electrical Engineering 115A — Analog Electronic Circuits I	4
Electrical Engineering 132A — Introduction to Communication Systems	4
HSSEAS GE Elective*	4
3rd Quarter	
Chemistry and Biochemistry 30A — Chemical Dynamics and Reactivity: Introduction to Organic Chemistry	4
Chemistry and Biochemistry 30AL — General Chemistry Laboratory	3
Electrical Engineering 115AL — Analog Electronics Laboratory I	2
Biomedical Engineering Elective†	4
Electrical Engineering Elective‡	4
TOTAL	**199**

*See page 22 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.
†See counselor, 6426 Boelter Hall, for details.
‡See page 65, 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 — Calculus and Analytic Geometry	4
HSSEAS GE Elective*	4
2nd Quarter	
Computer Science 32 — Introduction to Computer Science II	4
English Composition 3 — English Composition, Rhetoric, and Language	5
Mathematics 31B — Calculus and Analytic Geometry	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 1 — Electrical Engineering Physics I	4
Mathematics 32B — Calculus of Several Variables	4
HSSEAS GE Electives (2)*	8
2nd Quarter	
Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems	4
Mathematics 33A — Linear Algebra and Applications	4
Physics 4BL — Electricity and Magnetism Laboratory	2
HSSEAS GE Elective*	4
3rd Quarter	
Electrical Engineering 2 — Physics for Electrical Engineers	4
Electrical Engineering 10 — Circuit Analysis I	4
Mathematics 33B — Infinite Series and Differential Equations	4
HSSEAS GE Elective*	4
JUNIOR YEAR	
1st Quarter	
Electrical Engineering 101 — Engineering Electromagnetics	4
Electrical Engineering 102 — Systems and Signals	4
Electrical Engineering 103 — Applied Numerical Computing	4
Electrical Engineering 110 — Circuit Analysis II	4
Electrical Engineering 110L — Circuit Measurements Laboratory	2
2nd Quarter	
Electrical Engineering 115A — Analog Electronic Circuits I	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
3rd Quarter	
Computer Science 111 — Operating Systems Principles	4
Electrical Engineering 113 — Digital Signal Processing	4
Electrical Engineering 115AL — Analog Electronics Laboratory I	2
Electrical Engineering M116D or Computer Science M152B — Digital Design Project Laboratory	4
Engineering Breadth†	4
SENIOR YEAR	
1st Quarter	
Electrical Engineering 115C — Digital Electronic Circuits	4
Electrical Engineering 131A — Probability	4
Technical Elective‡	4
HSSEAS GE Elective*	4
2nd Quarter	
Computer Science 180 — Introduction to Algorithms and Complexity	4
Mechanical and Aerospace Engineering 192A — Mathematics of Engineering	4
Technical Electives‡	8
3rd Quarter	
Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)	4
Technical Elective‡	4
HSSEAS GE Elective*	4
TOTAL	**190**

*See page 22 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.
†Course must be selected from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A).
‡See page 65, Computer Engineering Option, item 3, for list of 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 88 — Freshman Seminar: New Materials	2
Mathematics 31A — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B — Calculus and Analytic Geometry	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) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)	4
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
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
Life Sciences Elective	4
HSSEAS GE Elective*	4
3rd 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 90L — Physical Measurement in Materials Engineering	2
Mathematics 33B — Infinite Series and Differential Equations	4
JUNIOR YEAR	
1st Quarter	
Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Laboratory	6
Materials Science and Engineering 130 — Phase Relations in Solids	4
Mechanical and Aerospace Engineering 102 — Mechanics of Particles and Rigid Bodies	4
Elective†	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
HSSEAS GE Elective*	4
SENIOR YEAR	
1st Quarter	
Materials Science and Engineering 160 — Introduction to Ceramics and Glasses	4
Materials Engineering Elective	4
HSSEAS GE Elective*	4
Upper Division Mathematics Elective	4
2nd Quarter	
Materials Science and Engineering 150 — Introduction to Polymers	4
Materials Science and Engineering 191L — Computer Methods and Instrumentation in Materials Science	2
Elective†	4
HSSEAS GE Elective*	4
3rd Quarter	
Materials Science and Engineering 161L — Laboratory in Ceramics	2
Materials Science and Engineering 190 — Materials Selection and Engineering Design	4
Elective†	4
HSSEAS GE Elective*	4
TOTAL	**182 or 183**

*See page 22 for details.
†See page 81, B.S. in Materials Engineering, item 4, for list of 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 88 — Freshman Seminar: New Materials	2
Mathematics 31A — Calculus and Analytic Geometry	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B — Calculus and Analytic Geometry	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*	4
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
Life Sciences Elective	4
3rd Quarter	
Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids	4
Electrical Engineering 10 — Circuit Analysis I	4
Materials Science and Engineering 90L — Physical Measurement in Materials Engineering	2
Mathematics 33B — Infinite Series and Differential Equations	4
HSSEAS GE Elective*	4
JUNIOR YEAR	
1st Quarter	
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
HSSEAS GE Elective*	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	
Electrical Engineering 122AL — Semiconductor Devices Laboratory	4
Mechanical and Aerospace Engineering 102 — Mechanics of Particles and Rigid Bodies	4
Electronic Materials Major Field Elective†	4
HSSEAS GE Elective*	4
2nd Quarter	
Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory	6
Electronic Materials Technical Electives (2)	8
Upper Division Mathematics Elective	4
3rd Quarter	
Materials Science and Engineering 190 — Materials Selection and Engineering Design	4
Electronic Materials Laboratory Elective	2
Electronic Materials Technical Electives (2)	8
TOTAL	**194 or 195**

*See page 22 for details.
†Select two from Materials Science and Engineering 132, 150, 160.

B.S. in Mechanical 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 — Calculus and Analytic Geometry	4
HSSEAS GE Elective*	4
2nd Quarter	
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory	7
Mathematics 31B — Calculus and Analytic Geometry	4
Physics 1A — Mechanics	5
3rd Quarter	
Mathematics 32A — Calculus of Several Variables	4
Mechanical and Aerospace Engineering 20 — FORTRAN 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
Mechanical and Aerospace Engineering 94 — Introduction to Computer-Aided Design and Drafting	4
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*	4
3rd Quarter	
Mathematics 33B — Infinite Series and 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*	4
JUNIOR YEAR	
1st Quarter	
Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids	4
Electrical Engineering 100 — Electrical and Electronic Circuits	4
Mechanical and Aerospace Engineering 105D — Transport Phenomena	4
Mechanical and Aerospace Engineering 192A — Mathematics of Engineering	4
2nd Quarter	
Mechanical and Aerospace Engineering 157 — Basic Mechanical Engineering Laboratory	4
Mechanical and Aerospace Engineering 169A — Introduction to Mechanical Vibrations	4
Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems	4
HSSEAS GE Elective*	4
3rd Quarter	
Electrical Engineering 110L — Circuit Measurements Laboratory	2
Mechanical and Aerospace Engineering 131A — Intermediate Heat Transfer	4
Mechanical and Aerospace Engineering 156A — Strength of Materials	4
Mechanical and Aerospace Engineering 193 — Introduction to Manufacturing Processes	4
HSSEAS GE Elective*	4
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
Mechanical Engineering Electives (2)	8
HSSEAS GE Elective*	4
TOTAL	**193**

*See page 22 for details.

Correspondence Directory

University of California, Los Angeles
Los Angeles, CA 90095-1361
http://www.ucla.edu/

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, 350 De Neve Drive; On-Campus Housing Assignment Office, 270 De Neve Drive
http://www.housing.ucla.edu/

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/

Biomedical Engineering Program, 7523 Boelter Hall
http://www.bme.ucla.edu/

Chemical 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.org/

Engineering and Science Career Services, 5289 Boelter Hall
http://www.career.ucla.edu/students/escpo.htm

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General Counseling, Jan J. LaBuda (310) 825-2514, jan@ea.ucla.edu

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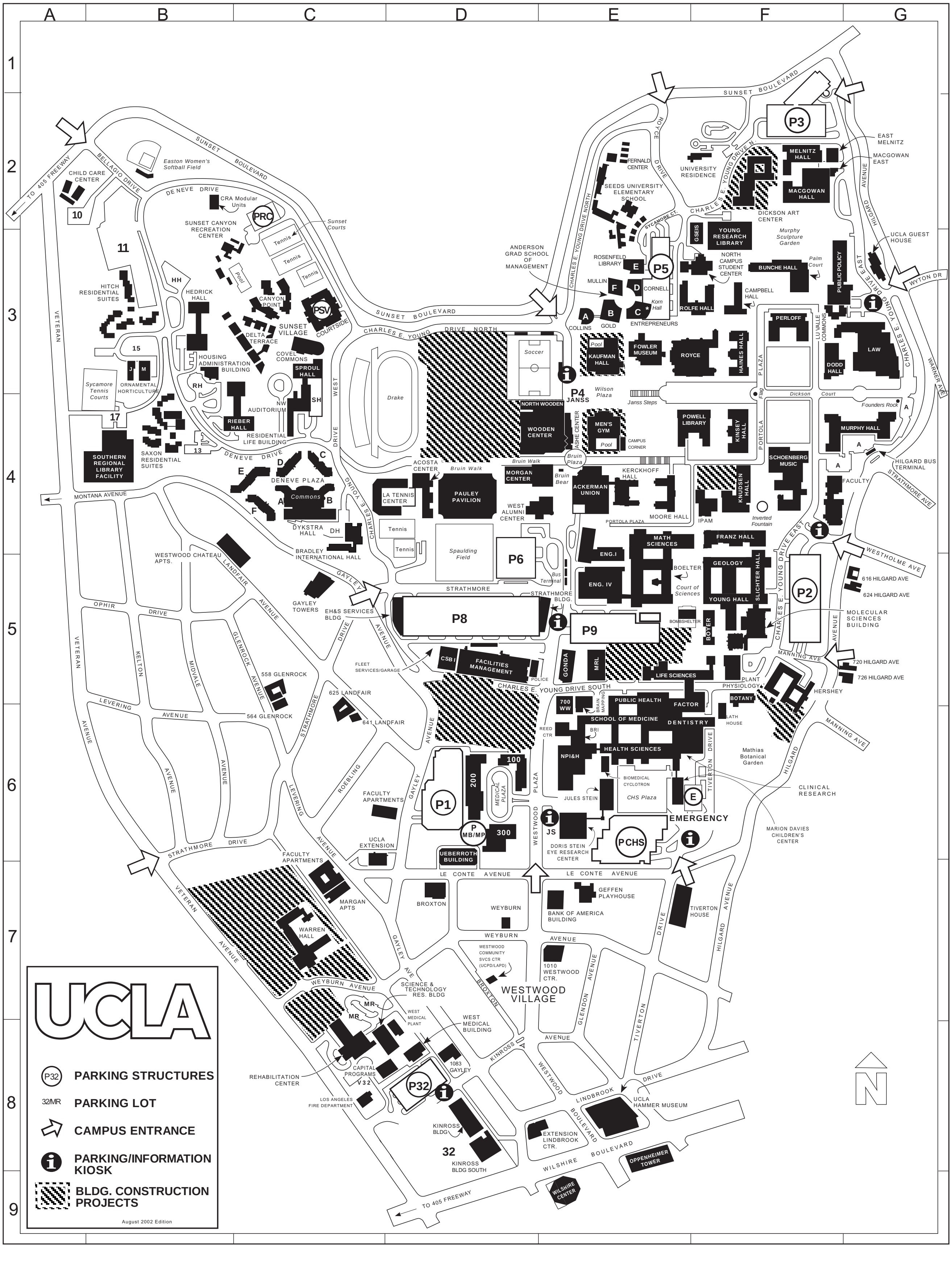
Campus Map



A
B
C
D
E
F
G
1
2
3
4
5
6
7
8
9
SUNSET BOULEVARD
Easton Women's Softball Field
CHILD CARE CENTER
TO 405 FREEWAY
BELLAGIO DRIVE
DE NEVE DRIVE
CRA Modular Units
PRC
SUNSET CANYON RECREATION CENTER
Sunset Courts
Tennis
Pool
HITCH RESIDENTIAL SUITES
HH
HEDRICK HALL
CANYON POINT
PSV
SUNSET VILLAGE
COURTSIDE
DELTA TERRACE
COVEL COMMONS
HOUSING ADMINISTRATION BUILDING
SPROUL HALL
SH
RH
NW AUDITORIUM
RIEBER HALL
RESIDENTIAL LIFE BUILDING
Sycamore Tennis Courts
ORNAMENTAL HORTICULTURE
SOUTHERN REGIONAL LIBRARY FACILITY
SAXON RESIDENTIAL SUITES
VETERAN
MONTANA AVENUE
DENEVE PLAZA
Commons
DYKSTRA HALL
DH
BRADLEY INTERNATIONAL HALL
WESTWOOD CHATEAU APTS.
LANDFAIR AVENUE
GAYLEY TOWERS
OPHIR DRIVE
LEVERING AVENUE
KELTON
MIDVALE
GLENROCK AVENUE
558 GLENROCK
564 GLENROCK
625 LANDFAIR
641 LANDFAIR
STRATHMORE
ROEBLING
FACULTY APARTMENTS
UCLA EXTENSION
STRATHMORE DRIVE
MARGAN APTS
WARREN HALL
WEYBURN AVENUE
SCIENCE & TECHNOLOGY RES. BLDG
MR
WEST MEDICAL PLANT
WEST MEDICAL BUILDING
REHABILITATION CENTER
CAPITAL PROGRAMS
V32
P32
LOS ANGELES FIRE DEPARTMENT
1083 GAYLEY
KINROSS BLDG
32
KINROSS BLDG SOUTH
TO 405 FREEWAY
CHARLES E. YOUNG DRIVE NORTH
Drake
Soccer
ACOSTA CENTER
Bruin Walk
LA TENNIS CENTER
PAULEY PAVILION
Tennis
Spaulding Field
P6
STRATHMORE
P8
EH&S SERVICES BLDG
FLEET SERVICES/GARAGE
CSB I
FACILITIES MANAGEMENT
POLICE
P1
200
100
MEDICAL PLAZA
300
P MB/MP
UEBERROTH BUILDING
BROXTON
WEYBURN
WESTWOOD COMMUNITY SVCS CTR (UCPD/LAPD)
WESTWOOD VILLAGE
KINROSS
ROYCE DRIVE
FERNALD CENTER
SEEDS UNIVERSITY ELEMENTARY SCHOOL
UNIVERSITY RESIDENCE
SYCAMORE CT.
ANDERSON GRAD SCHOOL OF MANAGEMENT
ROSENFELD LIBRARY
MULLIN
CORNELL
Korn Hall
ENTREPRENEURS
COLLINS
GOLD
P5
GSEIS
YOUNG RESEARCH LIBRARY
NORTH CAMPUS STUDENT CENTER
CAMPBELL HALL
ROLFE HALL
BUNCHE HALL
Palm Court
Murphy Sculpture Garden
DICKSON ART CENTER
P3
MELNITZ HALL
MACGOWAN HALL
EAST MELNITZ
MACGOWAN EAST
UCLA GUEST HOUSE
PUBLIC POLICY
WYTON DR
HILGARD AVENUE
KAUFMAN HALL
Pool
FOWLER MUSEUM
ROYCE
HAINES HALL
PERLOFF
LU VALLE COMMONS
LAW
DODD HALL
Wilson Plaza
P4
JANSS
Janss Steps
Dickson Court
Founders Rock
NORTH WOODEN
WOODEN CENTER
MEN'S GYM
CAMPUS CORNER
POWELL LIBRARY
KINSEY HALL
MURPHY HALL
SCHOENBERG MUSIC
Bruin Plaza
MORGAN CENTER
Bruin Bear
ACKERMAN UNION
KERCKHOFF HALL
KNUDSEN HALL
FACULTY
HILGARD BUS TERMINAL
STRATHMORE AVE
WEST ALUMNI CENTER
MOORE HALL
IPAM
Inverted Fountain
PORTOLA PLAZA
MATH SCIENCES
FRANZ HALL
WESTHOLME AVE
ENG. I
BOELTER
GEOLOGY
SLICHTER HALL
Court of Sciences
ENG. IV
YOUNG HALL
P2
616 HILGARD AVE
624 HILGARD AVE
Bus Terminal
STRATHMORE BLDG.
P9
BOMBSHELTER
BOYER
MOLECULAR SCIENCES BUILDING
GONDA
MRL
LIFE SCIENCES
D
MANNING AVE
720 HILGARD AVE
726 HILGARD AVE
PLANT PHYSIOLOGY
BOTANY
HERSHEY
CHARLES E. YOUNG DRIVE SOUTH
700 WW
PUBLIC HEALTH
FACTOR
SCHOOL OF MEDICINE
DENTISTRY
LATH HOUSE
REED CTR
BRI
HEALTH SCIENCES
NPI&H
Mathias Botanical Garden
BIOMEDICAL CYCLOTRON
JULES STEIN
CHS Plaza
E
TIVERTON DRIVE
CLINICAL RESEARCH
JS
EMERGENCY
MARION DAVIES CHILDREN'S CENTER
DORIS STEIN EYE RESEARCH CENTER
PCHS
LE CONTE AVENUE
GEFFEN PLAYHOUSE
BANK OF AMERICA BUILDING
TIVERTON HOUSE
1010 WESTWOOD CTR.
GLENDON AVENUE
TIVERTON
WESTWOOD
LINDBROOK DRIVE
UCLA HAMMER MUSEUM
EXTENSION LINDBROOK CTR.
WILSHIRE BOULEVARD
OPPENHEIMER TOWER
WILSHIRE CENTER
N
UCLA
PARKING STRUCTURES
32MR PARKING LOT
CAMPUS ENTRANCE
PARKING/INFORMATION KIOSK
BLDG. CONSTRUCTION PROJECTS
August 2002 Edition

Legend

CAMPUS BUILDINGS	Grid	Delivery Street Address
Ackerman Student Union	E4	308 Westwood Plaza
Acosta Training Center	D4	301 Westwood Plaza
Anderson Graduate School of Management	E3	
A - Collins Executive Education Center	E3	110 Westwood Plaza
B - Gold Hall	E3	110 Westwood Plaza
C - Entrepreneurs Hall	E3	110 Westwood Plaza
D - Cornell Hall	E3	110 Westwood Plaza
E - Rosenfeld Library	E3	110 Westwood Plaza
F - Mullin Mgmt Commons	E3	110 Westwood Plaza
* - Korn Convocation Hall	E3	110 Westwood Plaza
Ashe Center	E4	221 Westwood Plaza
Bank of America Bldg.	E7	924 Westwood Blvd.
Biomedical Cyclotron	E6	780 Westwood Plaza
Boelter Hall (Engineering II & III)	E5	580 Portola Plaza
Bombshelter Food Facility	E5	675 Charles E. Young Dr. South
Botany	F5	618 Charles E. Young Dr. South
Boyer Hall (formerly MBI)	F5	611 Charles E. Young Dr. East
Brain Mapping	E5	660 Charles E. Young Dr. South
Brain Research Institute (BRI)	E5	670 Charles E. Young Dr. South
Bradley International Hall	C4	417 Charles E. Young Dr. West
Broxton Plaza	D7	911 S. Broxton
Bunche Hall	F3	315 Portola Plaza
Campbell Hall	F3	335 Portola Plaza
Campus Corner Food Facility	F3	308 Westwood Plaza
Campus Services Bldg. I	D5	741 Charles E. Young Dr. South
Canyon Point (Sunset Village)	C3	200 DeNeve Dr.
Capital Programs Bldg.	D8	1060 Veteran Ave.
Career Center (Strathmore Bldg.)	D5	555 Westwood Plaza
Center for Health Sciences	G5	10833 LeConte Ave.
Child Care Center	A2	101 Bellagio Dr.
Clinical Research	F6	700 Tiverton Ave.
Courtside (Sunset Village)	C3	200 DeNeve Dr.
Covel Commons (Sunset Village)	C3	200 DeNeve Dr.
Delta Terrace (Sunset Village)	C3	200 DeNeve Dr.
Dentistry, School of	F5	714 Tiverton Ave.
DeNeve Housing Complex	C4	
A - Acacia Residential Bldg.	C4	341 Charles E. Young Dr. West
B - Birch Residential Bldg.	C4	361 Charles E. Young Dr. West
C - Cedar Residential Bldg.	C4	301 Charles E. Young Dr. West
D - Dogwood Residential Bldg.	C4	321 Charles E. Young Dr. West
E - Evergreen Residential Bldg.	C4	331 Charles E. Young Dr. West
F - Firgrove Residential Bldg.	C4	381 Charles E. Young Dr. West
Pavilion Bldg./Student Commons	C4	351 Charles E. Young Dr. West
Dickson Art Center	F2	240 Charles E. Young Dr. North
Dodd Hall	F3	390 Portola Plaza
Doris Stein Eye Research Center	E6	200 Stein Plaza
Drake Track & Field Stadium	C4	340 Charles E. Young Dr. North
Dykstra Hall	C4	401 Charles E. Young Dr. West
East Melnitz	B7	235 Charles E. Young Dr. East
Easton Women's Softball Field	B2	100 DeNeve Dr.
EH&S Services Bldg.	D5	550 Charles E. Young Dr. West
Engineering I	E4	404 Westwood Plaza
Engineering IV	E4	420 Westwood Plaza
Extension Lindbrook Center	D8	10934-10936 Lindbrook Dr.
Facilities Management Bldg.	D5	731 Charles E. Young Dr. South
Factor Health Sciences Bldg.	F5	700 Tiverton Ave.
Faculty Center	F4	480 Charles E. Young Dr. East
Faculty Housing	C7	715 Gayley & 827 Levering
Fernald Center	E2	10620 Sunset Blvd.
Fleet Services/Garage	D5	752 Charles E. Young Dr. South
Fowler Museum of Cultural History	E3	308 Charles E. Young Dr. North
Franz Hall	E6	502 Portola Plaza
Geffen Playhouse	E7	10886 LeConte Ave.
Geology Bldg.	F5	595 Charles E. Young Dr. East
Gonda (Goldschmied) Center	E5	695 Charles E. Young Dr. South
Graduate School of Education & Information Studies (GSEIS)	E3	290 Charles E. Young Dr. North
Haines Hall	F3	375 Portola Plaza
Hedrick Hall	B3	250 DeNeve Dr.
Hershey Hall	F5	801 Hilgard Ave.
Hilgard Bus Terminal	G4	403 Hilgard Ave.
Hitch Residential Suites	B3	245 DeNeve Dr.
Housing Administration Bldg.	B3	270 DeNeve Dr.
Institute for Pure & Applied Mathematics	F4	460 Portola Plaza
Jules Stein Eye Institute	E6	100 Stein Plaza
Kaufman Hall (formerly Dance)	E3	120 Westwood Plaza
Kerckhoff Hall	E4	308 Westwood Plaza
Kinross Bldg.	D8	11000 Kinross Ave.
Kinross Bldg. South	D9	11020 Kinross Ave.
Kinsey Hall	F4	415 Portola Plaza
Knudsen Hall	F4	475 Portola Plaza
Law, School of	G3	385 Charles E. Young Dr. East
Landfair Apartments	C5	625-641 Landfair Ave.
Life Sciences Bldg.	E5	621 Charles E. Young Dr. South
Los Angeles Tennis Center	D4	420 Charles E. Young Dr. West
Lu Valle Commons	F3	398 Portola Plaza
MacDonald Medical Research Labs (MRL)	E5	675 Charles E. Young Dr. South
Macgowan Hall	F2	245 Charles E. Young Dr. East
Macgowan East	F2	243 Charles E. Young Dr. East
Mail, Document & Distribution Services (Strathmore Bldg.)	D5	555 Weswood Plaza
Marion Davies Children's Center	E6	805 Tiverton Ave.

CAMPUS BUILDINGS	Grid	Delivery Street Address
Mathematical Sciences Bldg.	E5	520 Portola Plaza
Mathias Botanical Garden Lath House	F6	707 Tiverton Ave.
Melnitz Hall	F2	235 Charles E. Young Dr. East
Men's Gymnasium	E4	220 Westwood Plaza
Molecular Sciences Bldg.	F5	609 Charles E. Young Dr. East
Moore Hall	E4	457 Portola Plaza
Morgan Intercollegiate Athletics Center	D4	301 1/2 Westwood Plaza
Medical Plaza 100 (MP100)	D6	100 Medical Plaza
Medical Plaza 200 (MP200)	D6	200 Medical Plaza
Medical Plaza 300 (MP300)	D6	300 Medical Plaza
Murphy Hall	F4	410 Charles E. Young Dr. East
Neuropsychiatric Inst. & Hospital (NPI&H)	E6	760 Westwood Plaza
North Campus Student Center	E3	295 Charles E. Young Dr. North
North Wooden	E4	221 Westwood Plaza
Northwest Campus Auditorium	C4	200 DeNeve Dr.
Ornamental Horticulture Bldg. "J"	B3	267 DeNeve Dr.
Ornamental Horticulture Bldg. "M"	B3	265 DeNeve Dr.
Oppenheimer Tower	E8	10880 Wilshire Blvd.
Parking Services (Strathmore Bldg.)	D5	555 Westwood Plaza
Pauley Pavilion	D4	301 Westwood Plaza
Perloff Hall	F3	365 Portola Plaza
Plant Physiology	F5	615 Charles E. Young Dr. South
Police Station	D5	601 Westwood Plaza
Public Health, School of	F5	615 Charles E. Young Dr. South
Public Policy Bldg.	F3	337 Charles E. Young Dr. East
Reed Neurological Research Center	E6	710 Westwood Plaza
Rehabilitation Center	C8	1000 Veteran Ave.
Residential Life Bldg.	B4	370 DeNeve Dr.
Rieber Hall	C4	310 DeNeve Dr.
Rolfe Hall	E3	345 Portola Plaza
Royce Hall	E3	10745 Dickson Plaza
Saxon Residential Suites	B4	325 DeNeve Dr.
Schoenberg Music Bldg.	F4	445 Charles E. Young Dr. East
Science & Technology Research Bldg.	C8	1004 Veteran Ave.
Seeds University Elementary School (UES)	E2	10630 Sunset Blvd.
Slichter Hall	F5	603 Charles E. Young Dr. East
Sproul Hall	C3	350 DeNeve Dr.
Strathmore Building	E5	501 & 555 Westwood Plaza
Sunset Canyon Recreation Center	C3	111 DeNeve Dr.
Tiverton Patient Family Guest House	E7	900 Tiverton Ave.
UCLA Extension	C6	10945 LeConte Ave.
UCLA Guest House	G3	330 Charles E. Young Dr. East
UCLA Hammer Museum	E8	10889 Wilshire Blvd.
Ueberroth Bldg.	D6	10945 LeConte Ave.
University Residence	F2	10570 Sunset Blvd.
Warren Hall	C7	900 Weyburn Place North
West Alumni Center	D4	325 Westwood Plaza
West Medical Bldg.	C8	1010 Veteran Ave.
Westwood Community Service Center	D7	1036B Broxton Ave.
Weyburn Bldg.	D7	10911 Weyburn Ave.
Wight Art Gallery	F2	240 Charles E. Young Dr. North
Wilshire Center	E9	10920 Wilshire Blvd.
Wooden Recreation and Sports Center	D4	221 Westwood Plaza
Young Hall	F5	607 Charles E. Young Dr. East
700 Westwood Plaza	E5	700 Westwood Plaza
1010 Westwood Center	E7	1010 Westwood Blvd.
1083 Gayley	D8	1083 Gayley Ave.

PARKING STRUCTURES

Parking - CHS South	E6	820 Westwood Plaza
Parking - Sunset Recreation	C2	111 DeNeve Dr.
Parking - Sunset Village	C3	200 DeNeve Dr.
Parking Structure - Lot 32	D8	165 Veteran Ave.
Parking Structure 1	D6	100 Medical Plaza
Parking Structure 2	F5	602 Charles E. Young Dr. East
Parking Structure 3	F2	215 Charles E. Young Dr. North
Parking Structure 4	D4	221 Westwood Plaza
Parking Structure 5	E5	302 Charles E. Young Dr. North
Parking Structure 6	D5	425 Westwood Plaza
Parking Structure 8	D5	555 Westwood Plaza
Parking Structure 9	E5	675 Charles E. Young Dr. South
Parking Structure E	F6	833 Tiverton Ave.

CAMPUS LIBRARIES

Arts Library	F3	1400 Public Policy Bldg.
Biomedical Library (Louise M. Darling)	E6	CHS (Factor), rm. 12-077
College Library	E4	Powell Library Bldg.
Law Library (Hugh & Hazel Darling)	G3	School of Law, rm. 1112
Management Library	E3	Rosenfeld Lib. (Anderson Complex)
Music Library	F4	Schoenberg Music Bldg., rm. 1102
Powell Library	E4	10740 Dickson Plaza
Science & Engineering Library/Chemistry	F5	Young Hall, rm. 4238
Science & Engineering Library/ Engineering and Mathematical Sciences	E5	Boelter Hall, rm. 8270
Science & Engineering Library/ Geology-Geophysics	F5	Geology, rm. 4697
Science & Engineering Library/Physics	F4	Kinsey Hall, rm. 213
Southern Regional Library Facility (SRLF)	B4	305 DeNeve Dr.
Young Research Library (YRL)	F2	280 Charles E. Young Dr. North