UCLA
HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE 2002-03

ANNOUNCEMENT
SEPTEMBER 27, 2002
UNIVERSITY OF CALIFORNIA, LOS ANGELES
A series of administrative publications of the University of California, Los Angeles, published six times a year (one issue in March, June, August, December, two issues in September) by UCLA Academic Publications, 405 Hilgard Avenue, Los Angeles, CA 90024-1429. Periodicals postage paid at Los Angeles, CA. © 2002 by The Regents of the University of California. POSTMASTER: Send address changes to UCLA, Mail Services, Box 951361, Los Angeles, CA 90095-1361.

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 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, and (5) seek access to education records at the request of the student and University Policies.

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 in 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 do so through a Request for External Affairs Information Restriction form available from Enrollment and Degree Services, 1113 Murphy Hall.

A copy of the Federal and State Laws, University Policies, and the UCLA Telephone Directory may be inspected in the office of the Information Practices Coordinator, 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.

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.gradnet.ucla.edu.
## Academic Calendar

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

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<tr>
<th>Event</th>
<th>Fall 2002</th>
<th>Winter 2003</th>
<th>Spring 2003</th>
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<tr>
<td>Filing period for undergraduate applications (file with UC</td>
<td>November 1-30, 2001</td>
<td>—</td>
<td>October 1-31, 2002</td>
</tr>
<tr>
<td>Undergraduate Application Processing Service, P.O. Box 23460, Oakland,</td>
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<tr>
<td>CA 94623-0460)</td>
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<tr>
<td>Last day to file application for graduate admission or</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
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<tr>
<td>readmission with complete credentials and application fee,</td>
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<tr>
<td>with Graduate Admissions/Student and Academic Affairs,</td>
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<td>1255 Murphy Hall, UCLA, Los Angeles, CA 90024-1428</td>
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<tr>
<td>Reentering students eligible to enroll should begin to receive</td>
<td>June 12</td>
<td>November 8</td>
<td>February 14</td>
</tr>
<tr>
<td>URSA notification letter at mailing address</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Last day to file Undergraduate Application for Readmission</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
</tr>
<tr>
<td>form at 1113 Murphy Hall (late applicants pay a $50 late payment fee)</td>
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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 safer 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

Officers of Administration
Vijay K. Dhir, Ph.D., Professor and Interim Dean of the Henry Samueli School of Engineering and Applied Science
Stephen E. Jacobsen, Ph.D., Professor and Associate Dean, Student Affairs and Financial Resources
Michael K. Stenstrom, Ph.D., Professor and Associate Dean, Research and Physical Resources
Mary Okino, Assistant Dean, Chief Financial Officer
Milos D. Ercegovac, Ph.D., Professor and Chair, Computer Science Department
H. Thomas Hahn, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Vasilios I. Manousiouthakis, Ph.D., Professor and Chair, Chemical Engineering Department
Yahya Rahmat-Samii, Ph.D., Professor and Chair, Electrical Engineering Department
King-Ning Tu, Ph.D., Professor and Chair, Materials Science and Engineering Department
William W-G. Yeh, Professor and Chair, Civil and Environmental Engineering Department

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, micro-electromechanical (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 specialties 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 telecommunication, 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, cataloging, 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 computer-ized 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. BruintrakSTM provides seniors and graduate students with opportunities to meet one-on-one with employers seeking entry-level job candidates. BruintrakSTM, 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 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 2003-04 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),

<table>
<thead>
<tr>
<th>2002-03 Annual UCLA Graduate and Undergraduate Fees</th>
<th>Graduate Students</th>
<th>Undergraduate Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>University registration fee</td>
<td>$ 713.00</td>
<td>$ 713.00</td>
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<tr>
<td>Educational fee</td>
<td>2,896.00</td>
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<td>Undergraduate Students Association fee</td>
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<td>72.27</td>
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<tr>
<td>Graduate Students Association fee</td>
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<tr>
<td>Ackerman Student Union fee</td>
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<tr>
<td>Seismic fee for Ackerman/Kerckhoff</td>
<td>113.00</td>
<td>113.00</td>
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<tr>
<td>Wooden Center fee</td>
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<td>39.00</td>
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<tr>
<td>Mandatory medical insurance</td>
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<td>564.00</td>
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<tr>
<td>Nonresident tuition</td>
<td>11,132.00</td>
<td>12,009.00</td>
</tr>
<tr>
<td>Total mandatory fees</td>
<td>$ 4,548.50</td>
<td>$15,870.50</td>
</tr>
</tbody>
</table>

*Fees are subject to revision without notice*
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 summer 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.

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

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

Precalculus 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 to 100 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.

CEED undergraduate mentors, field trips, 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
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.

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

EGSA Engineering Graduate Students Association

AISW 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 Computer Science Honor Society

Epsilon

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/wnnews/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 aca-

demic 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
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/
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

<table>
<thead>
<tr>
<th>LOWER DIVISION PREPARATION FOR THE MAJORS</th>
<th>UCLA Equivalent Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mathematics</strong></td>
<td></td>
</tr>
<tr>
<td>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)</td>
<td>Mathematics 31A, 31B</td>
</tr>
<tr>
<td>Physical science</td>
<td>Physics 1A*, 1B*, 1C*, 4AL*, 4BL*</td>
</tr>
<tr>
<td>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)</td>
<td>Mathematics 32A, 32B</td>
</tr>
<tr>
<td>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</td>
<td>Mathematics 33A, 33B</td>
</tr>
</tbody>
</table>

**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 20A, 20AL, 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.

<table>
<thead>
<tr>
<th>AP Test</th>
<th>Score</th>
<th>UCLA Lower Division Units and Course Equivalents</th>
<th>Credit Allowed for University and GE Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td>3, 4, or 5</td>
<td><strong>8 units maximum for all tests</strong></td>
<td></td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>General Portfolio (no longer offered)</td>
<td>3, 4, or 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>4 GE units plus 4 unassigned units</td>
<td>4 units toward life sciences requirement</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3, 4, or 5</td>
<td>8 units (credit determined on an individual basis)</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science</td>
<td>3, 4, or 5</td>
<td><strong>4 units maximum for both tests</strong></td>
<td></td>
</tr>
<tr>
<td>Computer Science (A Test)</td>
<td>3, 4, or 5</td>
<td>2 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science (AB Test)</td>
<td>3</td>
<td>Credit determined on an individual basis</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Computer Science 31 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td>3</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 2 (4 units)</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 1 (4 units)</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>English</td>
<td>3</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 unassigned units</td>
<td>Satisfies Subject A requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 unassigned units</td>
<td>Satisfies Subject A requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 unassigned units</td>
<td>Satisfies Subject A requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 unassigned units</td>
<td>Satisfies Subject A requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 GE units</td>
<td>4 units toward life sciences requirement</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td>3, 4, or 5</td>
<td>4 GE units</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 GE units</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 GE units</td>
<td>4 units toward social sciences requirement, satisfies American History and Institutions requirement</td>
</tr>
<tr>
<td>History</td>
<td>3, 4, or 5</td>
<td>History 1C (4 units) plus 4 unassigned units</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>European</td>
<td>3, 4, or 5</td>
<td>8 unassigned units</td>
<td>Satisfies American History and Institutions requirement</td>
</tr>
<tr>
<td>Field</td>
<td>Units</td>
<td>Courses</td>
<td>Notes</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------</td>
<td>---------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 4 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 5 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 6 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td>Latin</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 4 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 5 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 6 (4 units) plus 4 unassigned units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td>3</td>
<td>Mathematics 31A (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Mathematics 31A, 31B (8 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td>3</td>
<td>8 units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Mathematics 31A, 31B (8 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Music</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Music Literature (no longer offered)</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td>3, 4, 5</td>
<td>8 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>3, 4, 5</td>
<td>4 units (credit determined on an individual basis)</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 units)</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>Statistics</td>
<td>3</td>
<td>4 unassigned units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Statistics 10 (4 units)</td>
<td>No application</td>
</tr>
</tbody>
</table>
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 UCLAs 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.seaosa.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 interdisciplinary 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, 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.Eng.) 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

Biocoustics, 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)

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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.

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/.

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.
Bioengineering

UCLA
7523 Boelter Hall
Box 951600
Los Angeles, CA 90095-1600
(310) 794-5945
fax: (310) 794-5956
http://www.bme.ucla.edu/

Carlo D. Montemagno, Ph.D., Chair

Professors
Warren S. Grundfest, M.D. FACS
Carlo D. Montemagno, Ph.D.

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

UCLA
7523 Boelter Hall
Box 951600
Los Angeles, CA 90095-1600
(310) 794-5945
fax: (310) 794-5956
e-mail: bme@ea.ucla.edu
http://www.bme.ucla.edu/

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)

*Faculty Advisory Committee

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)
Warren S. Grundfest, M.D. FACS (Electrical Engineering, Surgery)
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*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, Biophysics)
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)
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Chang-Jin Kim, Ph.D. (Mechanical and Aerospace Engineering)
J. John Kim, Ph.D. (Mechanical and Aerospace Engineering)
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Elliott M. Landaw, M.D., Ph.D. (Biostatistics)
Andrew F. Leuchter, M.D. (Psychiatry and Biobehavioral Sciences)
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Carlo D. Montemagno, Ph.D. (Mechanical and Aerospace Engineering)
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Peter M. Narins, Ph.D. (Physiological Science)
Stanley Nelson, M.D. (Human Genetics)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
D. Stott Parker, Jr., Ph.D. (Computer Science)
Yahya Rahmat-Samii, Ph.D. (Electrical Engineering)
Shiomo, 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)
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.


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...

Scope and Objectives
The Biomedical Engineering Interdepartmental Program trains specially qualified engineers and scientists to work on engineering applications in either medicine or biotechnology.
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; biomanufacturing 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.


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.


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.


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.

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 primarily 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 chair who then meet to assign advisers based 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.


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 al-
committee before students advance to must be approved by the dissertation present a dissertation proposal, which examinations. For the University Oral Qualifying administers the oral and final examinations of the Ph.D. dissertation and committee provides advice on the science and engineering faculty, who members, representing both neuroengineering seminar. In addition to the round of 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.

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)

gebraw, 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.


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


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 and 113. 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.
CM103. Human Physiology for Biomedical Engineers. (4) (Formerly numbered M103.) (Same as Physiology M103.) 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 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 10B). 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. Requisites: 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 circuit configurations, amplifiers, and passive filters; computerized data acquisition using LabView 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 and finite element 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. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarray technology, protein-based diagnostics, genomics and bioinformatics, isolation of human tissues, human body and cell morphology, and tissue engineering. Concurrently scheduled with course CM245. Letter grading. Mr. Liao (F)

C150L. Introduction to Micromachining and Microelectromechanical Systems Laboratory. (4) (Same as Electrical Engineering C150L and Mechanical and Aerospace Engineering M180L.) Lecture, three hours; laboratory, four hours; outside study, five hours. Requisites: Electrical Engineering 1 or Physics 1C, Chemistry 20. Introduction to fabrication technology and systems for micromachining and microelectromechanical systems (MEMS). Fundamentals of micromanipulation 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 using hands-on micromanipulation 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 173, Physics 17, Computer science course C170L. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications, with emphasis on mechanisms of fundamental interactions 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 for temperature distribution measurements. Concurrently scheduled with course C270L. Letter grading.


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 natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM620. Letter grading.

Mr. Wu (W)

C181. Biomaterials-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisite: course C180. In-depth exploration of host cellular response to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, immune response, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C281. Letter grading. Mr. Wu (Sp)


Mr. Wu (Sp)

C196A. 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 hours. P/NP grading.

Mr. Wu (Sp)

M196B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science M196B, Biophysics M196B, and Biophysics ME196B, and ME196B) Lecture, four hours; discussion, one hour; laboratory, two hours. Requisite: Electrical Engineering 102 or Mathematics 115A. Introduction to dynamic system modeling, computational modeling, and computer simulation methods for studying biomedical systems. Basics of numerical simulation algorithms, translating modeling goals and data into mathematical models and implementing them for simulation and analysis. Modeling software exploited for class assignments in PC laboratory. Letter grading. Mr. DiStefano (W)

C196L. Biomedical Systems/Biocomputing Research Laboratory. (2 to 4) (Same as Computer Science M196L, and Biophysics 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. Automation and safety. Comprehensive experiment design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM296L. Letter grading.

Graduate Courses

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

CM202. Human Anatomy for Biomedical Engineers. (4) (Same as Physiological Science CM202.) 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 study of specific systems pertinent to biomedical research. Concurrently scheduled with course CM102. Letter grading. Mr. Montrongino (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. Montrongino (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 technology 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.
C270. Energy-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 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 C170L. Letter grading.

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.


C272. 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.

C281. 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 C181L. Letter grading.

C282. 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 interface properties. Discussion of morphology and composition of biomaterials and nanoscale, mesoscale, and macroscale, 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: courses 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 biologically active signals. Concurrently scheduled with course C185L. Letter grading. Mr. Wu (Sp)

C250A. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Electrical Engineering M250A. 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. Issues such as chemical resistance, mechanical properties, and residual intrinsic stress. Letter grading. Mr. Judy (W)

C250B. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Electrical Engineering M250B. 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.


259H. Biomechanics of Traumatic Injury. (4) (Same as Environmental Health Sciences M259H.) Lecture, four hours; outside study, eight hours. Requisite: grading. Requisite: course CM140 or Mechanical and Aerospace Engineering 108, 156A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamic modeling and simulation applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140L. Letter grading.

CM242. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM242.) 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. Dynamic modeling and simulation applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140L. Letter grading.

CM245. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM245.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course CM140 or Mechanical and Aerospace Engineering 108, 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 circuits for use in data acquisition process, including bridge completion circuits, amplifiers, and passive filters; computerized data acquisition using LabView and A/D input/output (I/O) board; strain measurements 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. Dynamic modeling and simulation applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140L. Letter grading.

CM241L. Biomechanics Laboratory. (4) Lecture, one hour; laboratory, three hours; outside study, eight hours. Requisite: course CM140 or Mechanical and Aerospace Engineering 108, 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 circuits for use in data acquisition process, including bridge completion circuits, amplifiers, and passive filters; computerized data acquisition using LabView and A/D input/output (I/O) board; strain measurements in presence of noise. Letter grading. Mr. Gupta (W)

CM225. Microfluidics. (4) (Same as Chemical Engineering CM225.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course CM140 or Mechanical and Aerospace Engineering 108, 156A. Introduction to microfluidics and microfluidic devices in medical and dental applications, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C170L. Letter grading.

CM220. Introduction to Biocatalysis. (4) (Same as Materials Science CM220.) 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.

CM212A-M212B-M212C. Literature in Neuroengineering. (2-2-2) concurrently scheduled with course C181. Letter grading. Mr. Judy (W)
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. Preparing research for and writing of M.S. candidates, including thesis prospectus. S/U grading.


Chemical Engineering

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Vasilios I. Manousiouthakis, Ph.D., Chair
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Professors
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James F. Davis, Ph.D., Associate Vice Chancellor
Selim M. Senkan, 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 Noble, 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
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

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
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 1, 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
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
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
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.gdnnet.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.

**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 School-wide 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 semi-synthetic colloids such as micelles and vesicles. Both standard fermentations at mesophilic and extremophilic cultures at extremes of temperature (up to 100°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 mi-
and storage (batteries), and bioelectrochemical processes and biomedical systems.

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

Electronic Materials Processing Laboratory

The Electronic Materials Processing Laboratory focuses on synthesizing and processing novel electronic materials for their applications in microelectronics 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, designed and built in the laboratory, makes it possible to probe the behavior of nanoparticle chain aggregates of a type produced commercially for use in nanocomposite materials; these aggregates are also released by sources of pollution such as diesel engines and incinerators.

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 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 process 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


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

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


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 (CO2 cycles), stratospheric ozone depletion (chlorine and ozone cycles), and global nitrogen cycles. Flow of materials in industrial economies compared and contrasted with natural flows; presentation of 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. Requires: 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, Newtonian law of viscosity, Navier-Stokes equations, interphase momentum transport and friction factors, flows in conduits and around submerged objects. Letter grading. Mr. Hicks (W,Sp)

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,Sp)

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. Ms. Chang, 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. Ms. Chang

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. (5) 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. Ms. Liao, Mr. Monbouquette (Sp)

104B. Chemical Engineering Laboratory II. (6) Lecture, two hours; laboratory, eight hours; outside study, eight hours; other, four hours; four, 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. Liao, Mr. Monbouquette (Sp)

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 water cleaning, oxidation, diffusion, lithography, Fundamentals of momentum transport, 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)


108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour. Requisites: courses 103, 104B, 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. Manousouthishakis (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. Focus on numerical and analytical techniques encompassing linear and non-linear 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, eight hours. Requisite: course 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 C214. Letter grading. Ms. Chang, Mr. Hicks (F)


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, electrolysis and electrochemical processes. May be concurrently scheduled with course C214. Letter grading.

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. Ms. Chang, 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)


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)


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, bioinformatics and genomics, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, and structure and composition 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: courses 101C and 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. (F)

Mr. Noe (F)

201. Methods of Mathematical Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 200 or Mathematics M222A 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. (F)

Mr. Liao, Mr. Senkan (W)


Mr. Liao, Mr. Senkan (W)

211. 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 cryogenic engineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading.

Mr. Liao, Mr. Senkan (W)


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, electrochemistry and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading.

Mr. Noe (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 105, or Chemistry 156. Use of previously learned concepts of biochemical chemistry, thermodynamics, and chemical kinetics. Computer tools to develop reaction mechanism and design of reactor 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, interfaces, and related processing 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 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 processes, relationships between molecular transport, convection, and electrode kinetics, along with applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading.

Mr. Noe (F)


Mr. Cohen (W)


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. Liao, 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 105, 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)


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.


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)


Mr. Friedlander (F)


CM245. Molecular Biotechnology for Engineers. (4) (Same as Biomedical Engineering CM245.) Lecture, four hours; discussion, one hour; outside study, eight hours. Topics include 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 and proteomics. Prequisite: courses M220A or M220B, M282A. S/U grading. (F, W, Sp)

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)


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.

280. Linear Dynamic Systems. (4) (Same as Electrical Engineering M280A 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 M280C 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.


283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: 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 space), (2) finite-dimensional dynamical systems (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. Christodides


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)

405A. 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 classroom for benefit of student learning. S/U grading. (F, W, Sp)

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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Jiun-Shyan Chen, Ph.D., Vice Chair
Patrick J. Fox, Ph.D., Vice Chair

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Jiann-Wen Ju, Ph.D.
Lawrence G. Selina, 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.
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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:

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

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

Systems Analysis. Civil and Environmental Engineering 106A

Transportation Engineering. Civil and Environmental Engineering 180


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. HSS/SEAS 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 135A, 141, 142.


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.


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.


Structural Mechanics

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

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


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.

The 2002 UCLA-ASCE concrete canoe team.
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 prospects 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.

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.

3. Soil Mechanics Laboratory. For standard experiments and advanced research in geotechnical engineering, with equipment for static and dynamic triaxial and simple shear testing. Modern 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 than 100 earthquake strong motion instruments in three campus buildings to measure the response of actual buildings during earthquakes. When combined with over 50 instruments placed in four Century City high-rises and retail buildings, this network, which is maintained by the U.S. Geological Society and State of California Division of Mines and Geology Strong Motion Program, represents the most detailed building instrumentation network in the world. The goal of the research conducted using the response of these buildings is to improve computer modeling methods and the ability of structural engineers to predict the performance of buildings during earthquakes.

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

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

- Reinforced concrete, earthquake engineering

Joan-S.-J. Ju, Ph.D. (UC Berkeley, 1986)

- Damage mechanics, mechanics of composite materials, computational plasticity, and computational mechanics

- Initial soil samples.
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 wind and wave loads, structural dynamics, and uncertainty and risk analysis of structures

Paul 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) 
Soil mechanics and foundation engineering, applied soil mechanics

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

Associate Professors

Jian-Shyan Chen, Ph.D. (Northwestern, 1989) 
Finite element methods, meshfree methods, large deformation mechanics, inelasticity, 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 Tacioglu, 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., 1985) 
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. Pradhan, 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. Introduces the scope of civil engineering profession, including earthquake, environmental, geotechnical, structural, transportation, and water resources engineering. P/NP grading. 


5. 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.

6. Introduction to Mechanics of Deformable Solids. (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.


9. 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 determinations, Design problems, laboratory report writing. Letter grading.

10. 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, tension, 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.


12. 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 determinations, Design problems, laboratory report writing. Letter grading.

13. 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, tension, 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.
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 structures; analysis of statically determinate trusses, 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, 10B. 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 trusses and frame structures using matrix methods: matrix force method; 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, finite element methods, weighted residual methods, Ritz method, least-squares method, Galerkin method, convergence criteria and rate of convergence, natural coordinates and shape functions, isoparametric finite elements, finite element formulation of multidimensional heat flow and elasticity, numerical integration and approximation properties, finite element formulation of beam. Letter grading.
Mr. Chen, Mr. Ju (Sp)

135L. Structural Design and Testing Laboratory. (2, 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, Mr. Ju (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 inverse spectral analysis for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams. Letter grading.
Mr. Ju (F)

137L. Structural Dynamics Laboratory. (2, 4)
Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibration of instrumentation for dynamic measurement. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic similarity. Letter grading.
Mr. Stolzenbach (F)

141. Steel Structures. (4)
Mr. Ju (F)

142. Design of Reinforced Concrete Structures. (4)
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 experimental and/or analytical techniques. Study of beams. Letter grading.
Mr. Wallace (Sp)

143. Design of Prestressed Concrete Structures. (4)
Mr. Selna (Sp)

144. Structural Systems Design. (4)
Mr. Wallace (Sp)

145. Design and Construction of Water 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 design 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 Geology. Precipitation,, stream flow analysis, flood frequency analysis, groundwater, snow hydrology, hydrologic simulation. Possible field trips. Letter grading.
Mr. Yeh (F)

151. Introduction to Water Resources Engineer- ing. (4)
Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 103. Principles of hydrology, flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic theory and practice. Introduction to system analysis and design applied to water resources engineering. Letter grading.
Mr. Yeh (W)

153. Introduction to Environmental Engineering Science. (4)

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 analysis, redox, photolytic processes, disinfection by-products, ozonation. Selected global chemical cycle(s). Letter grading.
Mr. Stenstrom (F)

155. Unit Operations and Processes for Water and Wastewater Treatment. (4)
Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 153. Biological, chemical, and physical methods used to modify water quality. Fundamentals of physicalular water, membrane processes, 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: courses 155 (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 organic and inorganic constituents. Selected experiments include solids, nitrogen, oxygen, liquid, chloride, 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, air, and soil pollution: sources, transformations, effects, and processes for removal of contaminants. Design of unit operations, pretreatment plants, design of water treatment plants, design of water and wastewater treatment plants, design of unit operations, design 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 Anal- ysis. (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. Ju (W)

164. Hazardous Waste Site Investigation and Re- mediation. (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)
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 queuing. 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. (W,Sp)

Graduate Courses


221. Advanced Foundation Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 121, 220. Stress distribution. Bearing capacity and settlement of shallow foundations, including 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, 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. Stewart (W)

223. Earth Retaining Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 121. Basic concepts of theory of earth pressures behind retaining structures, with special application to design of retaining walls, bulkheads, sheet piles, and excavation bracing. Effects of flexibility, creep in soils, and construction techniques on stability of bulkheads and sheet piles. Mechanical stabilization of soft soils 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. Analysis 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)

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


234. Advanced Topics in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Limited to graduate engineering students. Current topics in composite materials, advanced 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 variation-al 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 non-linear equations; incremental, iterative, programming methods. Letter grading. Mr. Ju, Mr. Taciorglu (Sp)


M166. 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)

M168. Environmental Microbiology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/seniors. Microbial cell and its metabolic capabilities, microbial populations and their potential, 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. Harper (F)

M169. Environmental Microbiology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/seniors. Microbial cell and its metabolic capabilities, microbial populations and their potential, 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. Harper (F)
243. Advanced Reinforced Concrete Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course 137, 141, 142, 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)


Mr. Ju (W)

247. Advanced Structural Dynamics for Civil Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 235A or 235B, 235A or 235B. Dynamics of linear systems subjected to stationary and nonstationary random excitations. Reliability studies related to first exceedance problems; fatigue failures. Applications in earth-quake, offshore, wind, and aerospace engineering. Letter grading.

Mr. Ju (Sp)


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 engineer- ing, ground motion, elasticity, plasticity, structural me- chanics, mechanics of composites, and constitutive modeling. May be repeated for credit. S/U grading.

Mr. Ju, Mr. Wallace (F,Sp)


Mr. Ju, Mr. Wallace (F,Sp)


Mr. Yeh (W)

250C. Mathematical Modeling of Contaminant Transport in Groundwater. (4) Lecture, four hours; laboratory, eight hours. Requisites: courses 250B, 255. Phenomena and mechanisms of hydrodynamic dispersion, governing equations of mass transport in porous media, various analytical and numerical solu- tions, determination of dispersion parameters by labor- atory and field experiments, coupled and mul- tiphase groundwater response, and 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 models and modeling techniques to water resources systems. Topics include reservoir management and operation; optimization; environmental and water pollution problems; decision making; 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, 111. Economic theory and applications to analy- sis and management of water and environmental problems; application of price theory to water re- source management and renewable resources; ben- efit-cost analysis with applications to water resources and environmental planning. Letter grading.

Mr. Yeh (Sp)


Mr. Stenstrom (F)


Mr. Ju, Mr. Wallace (F,Sp)


Mr. Bendiksen, Mr. Ju (W)

258A. Membrane Separations in Aquatic Sys- tems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Applications of mem- brane separations to desalination, water reclamation, brine disposal, and ultrapure water systems. Discus- sion of reverse osmosis, ultrafiltration, electrodeionization, and ion exchange technologies from both practical and theoretical standpoints. Letter grading.

Mr. Stenstrom (W)

259A. Selected Topics in Environmental Engi- neering. (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 im- pacts. May be repeated for credit. S/U grading.

Mr. Harmon (F,Sp)

259B. Selected Topics in Water Resources. (2 to 4) Lecture, four hours; outside study, eight hours. Requir- es: course 244. Overview of current research and develop- ment in environmental engineering. Water and wastewater treatment systems, nonpoint pollution, multimedia im- pacts. May be repeated for credit. S/U grading.

Mr. Stenstrom (F,Sp)

260. Engineering Structural Analysis. (4) Lecture, four hours; outside study, eight hours. Emphasis on the development of mathematical models and modeling techniques to treat damage in the structural system and the resulting damage. Applications to water resources and environmental planning. Letter grading.

Mr. Stenstrom (F)


Mr. Wallace (F)
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, multiblock objective water resources planning, and optimization of water resources systems. Topics may vary from term to term. Letter grading.

Mr. Yeh (Sp)


Mr. Stenstrom (Sp)

M262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric Sciences M263A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, thermochemistry, spectroscopy, and photochemistry; chemical composition of Earth’s atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmosphere chemical processes, air pollution dispersion in urban complexes; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading.

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; applications of air pollution models. S/U or letter grading.

Mr. Stolzenbach (W)

263A. Physics of Environmental Transport. (4) (Formerly numbered 263.) 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)

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

Mr. Stolzenbach (W)

265A. Mass Transfer in Environmental Systems. (4) Lecture, four hours; computer applications, two hours; outside study, six 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, 256A. 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)


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.

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.

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.

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.

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

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

597C. Preparation for Ph.D. Oral Qualifying Exam. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. 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.


Computer Science

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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. Friedman Professor of Knowledge Sciences)
Lixia Zhang, Ph.D.

Professors Emeriti

Aligrides A. Avizienis, Ph.D.
Bertram Russel, Ph.D.
Jack W. Carlyle, Ph.D.
Gerald Estrin, Ph.D.
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Associate Professors

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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.
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).

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 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:


**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, queuing theory, queuing 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.

<table>
<thead>
<tr>
<th>Areas Included in the Computer Networks Field</th>
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<tr>
<td><strong>Typical Systems Studied</strong></td>
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<td><strong>Tools Used</strong></td>
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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.

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 re-usable 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 described 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/csdl/research/labs/cs/

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://arithmetic.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://kmmed-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://iecs.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 department 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

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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 communication 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

  Artificial intelligence

  Multimedia systems, database systems, data mining

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

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

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

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

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

Professors Emeriti

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

Bertram Bussell, Ph.D. (UCLA, 1962)
  Computer systems architecture, interactive computer graphics

Jack W. Carlyle, Ph.D. (UC Berkeley, 1961)
  Communication, computation theory and practice, algorithms, grammatical 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

Judith Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1965)
  Decision analysis, human information processing, artificial intelligence, pattern recognition, machine learning, mathematical analysis of systems, complexity of computations

  Information processing in biological systems, with emphasis on neurosciences, 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 Bayesian 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

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

Elias Koutsoopoulos, 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

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

Yuval Tamir, Ph.D. (U.C Berkeley, 1985)
  Computer architecture, VLSI

Assistant Professors

Jung Hoo (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 database systems

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. 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.

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. Korf

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 Mathematical 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. Abstraction of data types, object-oriented programming. Examples and exercises from computer science theory and applications. Letter grading. Mr. Cong (F,W)


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) devices, memory management, file systems. Letter grading. Mr. Potkonjak (F,Sp)

M51A. Logic Design of Digital Systems. (4) Formerly numbered 51A. (Same as Electrical Engineering M116.) 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,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 multiprocessing and multiprocessor systems; interrupts, process model, and interlocks. Resource allocation models and problem of deadlock. Scheduling, synchronization, mutual exclusion, 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: course 111 or equivalent for advanced seneors. 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. (5) Lecture, four hours; discussion, four hours; outside study, 10 hours. Not open to students with credit for course M171L. Introduction to fundamental data transmission 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)


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 4, LISP, MODULA 2, and PROLOG to illustrate particular implementations of some of above features. Letter grading.

Mr. Bagrodia (F,Sp)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 131, 181. Compiler structure: lexical analysis, syntax analysis, code generation, function 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, efficient and parallel algorithms. Parallel languages: MPI, MAJISE: primitives for parallel computation: specification of parallelism, interprocess communication and synchronization; design of parallel programs for scientific computation and distributed systems. Letter grading.

Mr. Cardenas, Mr. Zaniolo (F,Sp)


Mr. Cardenas, Mr. Zaniolo (F,Sp)

151B. 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 M116. Recommended: courses 111, and M152A or Electrical Engineering M1116C. Computer system design and implementation. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and implementation, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading.

Mr. Cong, Mr. Rennels, Mr. Tamir (F,Sp)


Mr. Ercogevac (W, odd years)

M512A. Introductory Digital Design Laboratory. (4) Formerly numbered 152A. (Same as Electrical Engineering M116L.) Laboratory, four hours; outside study, two hours. Requisite: course M51A or Electrical Engineering M116. Hands-on design, implementation, and debugging of course structures using computer-aided design tools for schematic capture and simulation, implementation of complex circuits used in programming digital logic. Letter grading. Mr. Rennels (F,Sp)

M512B. 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 systems 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 (F,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. Premaratne (F,Sp)


Mr. Dyer (W)


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 171LL) (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 friendly setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modern, PCs, and workstations in experiments on pulse transmission impairments, hardware and systems concepts. Letter grading. Mr. Gerla (F,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 and lower bounds; asymptotic complexity; NP-completeness. 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 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 115A. Lecture, four hours. Requisites: Mathematics 31A, 31B. Program in Computer Science. Enrolls 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 biomedical engineering 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 and Cybernetics M196B, and Medicine M196B) Lecture, four hours; discussion, one hour; laboratory, two hours. Requisites: course M196B. Special laboratory techniques and experience in bioboyernetics 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 experimental design. Radioisotope and kinetic studies. Experimental animals, controls. Consequently scheduled with course CM196L. Letter grading. Mr. Distefano

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 bioboyernetics 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 experimental design. Radioisotope and kinetic studies. Experimental animals, controls. Consequently scheduled with course CM196L. Letter grading. Mr. Distefano

199. Special Studies. (2 to 8) Instructor, 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,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 system 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)


212B. Queueing Applications: Scheduling Algorithms and Queueing Networks. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 118. Designed for graduate students. Important new class of distributed computing systems that support monitoring and manipulation of physical spaces through wireless sensor networks. Study of distributed protocols needed to realize these systems. Protocols developed for energy and otherwise resource-constrained nodes, network self-configuration and adaptation, localization and time synchronization, programming paradigms, application-level software, and local interfaces in computer communication links; national and international standards; tests and measurements. 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. Design, analysis, programming of local area networks, medium access protocols, formal data transmissions via analog signaling in computer communications; media characteristics, systems methodologies, performance analysis; modem signaling; physical interfaces in computer communication links; national and 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 characteristics; 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; SDL, 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 architectures 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 SPM), support for integrated services, World Wide Web, multimedia applications to Internet, fundamental protocol design and implementations. Letter grading. Mr. Zhang


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. May be repeated for credit with consent of instructor. Letter grading.

M222. Control and Coordination in Economics. (4) (S) Lecture, four hours; outside study, eight hours. Recommended preparation: appropriate mathematics course. Designed for graduate economics and engineering students. Stabilization policies, short- and long-run dynamics and stability analysis; decentralized systems, certainty equivalent and separation theorems; stochastic and learning models. Bayesian approach to price and output decisions. Sr or Jr. 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 meta-modeling; basic information and computation models; axiomatic systems; domain theory; least fixed point theory; well-founded induction. Logical models: sentences, axioms and rules, normal forms, derivations 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 multway 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 verification of 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 141. Theoretical and technical 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 issues in knowledge representation and data mining techniques. Letter grading. Mr. Zaniolo (F)

240B. Advanced Data and Knowledge Bases. (4) (Formerly numbered 242A.) Lecture, four hours; outside study, eight hours. Requisites: courses 143, 240A. Logical programming for data and knowledge representation. 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. Mintz, Mr. Parker, Mr. Zaniolo

241A. Object-Oriented and Semantic Database Systems. (3) Lecture, three and one-half hours; laboratory, one hour; outside study, eight hours. Requisite: course 143. Object and database principles. Data models and accessing. Database design and organization. Object-oriented 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, four hours; 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. Pictorial and multimedia database systems. Data-base 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, distributed databases. Techniques and implementation of data management 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 commercial fault-tolerant systems. Requisite: current research results. Letter grading. Mr. Rennels (W)

245A. Intelligent Information System. (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 (Sp)

245B. 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 processor design, logic synthesis, cache and memory organization, the relationship between hardware and 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 141A. SIMD and MIMD systems, symmetric multiprocessors, distributed-shared-memory systems, message-passing systems, clusters, interconnection networks, user-level host-network interfaces, switching element design, communication primitives, cache coherence, 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 or corequisite: course 251A. Fundamental concepts of computer arithmetic, high-performance, and 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 of applications and fault-tolerant software. 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 fault-tolerant computer systems. Analytic models and measures, modeling tools. Design for critical applications: long-life, real-time, and high-availability systems. Tolerance of design faults; design of applications and fault-tolerant software. Letter grading. Mr. Ercegovac (F)


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. Design and implementation of memory systems; control, access modes, hierarchies, and allocation algorithms. Characteristics, system organization, and device considerations of ferroelectric 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, interprocessor communication, task response time model, process scheduling, message passing protocols, replicated file systems, interface, cache memory, actor model, fine grain microcomputers, distributed operating system kernel, error recovery strategy, performance monitoring and measurement, scalability and maintainability, prototypes and commercial distributed systems. Letter grading. Mr. Chu (W)


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268A. Problem Solving and Search. (4) Lecture, four hours; outside study, eight hours. Requisite: course 23. Examination in depth 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.

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


Mr. Pearl

258E. Foundations of VLSI CAD Algorithms. (4) Lecture, four hours; outside study, eight hours. Preparation: course 258D. Lecture, four hours; research laboratory, four hours. Requisite: course 258A. 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 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: course 258D. Lecture, four hours; research laboratory, four hours. Requisite: course 258A. 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 wiring. Letter grading.

Mr. Cong (W)

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 258E. Detailed study of various problems in logic 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 diagram (BDDs). Letter grading.

Mr. Cong

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 258A, 258G. Detailed study of various problems in analysis and design of high-speed VLSI interconnects at both integrated circuit (IC) and packaging levels, including interconnect capacitance and resistance, lossless and performance-based line, 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 design in which instructor has developed special proficiency as a consequence of research interests. Students required to prepare a paper analyzing 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. Recommended preparation: Computer Engineering 103 or Mathematics 151B or comparable experience with numerical computing. Designed for graduate computer science students. Principles of computer treatment of selected numerical problems in algebraic and differential systems, transforms and spectra, data acquisition and reduction; emphasis on concepts underlying and simulation and the applicability of contemporary developments in numerical software. Computer exercises. Letter grading.


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. Techniques for processing engineering and statistical data. Algorithms to evaluate recursive filter functions, Fourier series, power spectrum, 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. Structured methods for processing 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 speech, images, video, and computer interfaces. 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 student literature in an area of computer science methodology in which instructor has developed special proficiency as a consequence of research interests. Students report on special 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 special topics 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 topics: 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, undecidability, and “easy” and “hard” problems. PTIME/NP-TIME. Letter grading. Ms. Greibach, Mr. Parker

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 281A. 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, undecidability, and “easy” and “hard” problems. PTIME/NP-TIME. Letter grading. Ms. Greibach

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 transfers. Letter grading. Mr. Gafni

284A-284Z. 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; proof of 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

289S. 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 in theoretical computer science, mathematics, and applications of algorithms and complexity models for parallel and concurrent computation, and formal language and automata theory. May be repeated for credit. S/U grading.

289A-289Z. 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. Applications of 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.

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. Ms. Greibach

M296A. Advanced Modeling Methodology for Dynamic Systems. (4) (Same as Biomedical Engineering M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: course 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmacological, chemical, control, and computer systems; multicomponent, noncomponental, and input/output models, linear and nonlinear. Emphasis on model application, limitations, and reliance 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)
Electrical Engineering

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Joel Schulman, Ph.D.

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

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Giorgio Franceschetti, Ph.D.
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Brian H. Kolner, Ph.D.
Neville C. Luhmann, Jr., Ph.D.
Joel Schulman, Ph.D.
Piyot V. Ulmshtev, Ph.D.

Adjunct Associate Professors
Bijan Houshmand, Ph.D.
Kenneth W. Illit, 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):

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

Graduate Study

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

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,
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.

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 advisor, 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 advisor, be selected as free electives from the 100 or 200 series in order to meet the overall requirements given above.


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.

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 advisor.

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 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 course load 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 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.


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
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.

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 wave-guiding 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 queuing 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
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-SiGe, 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.

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.
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 8500-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 school-wide programs in device fabrication, such as MEMS and optoelectronics. For more information, see http://www.nanolab.ucla.edu/.

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

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

These laboratories are open to undergraduate and graduate students who have faculty sponsorship for their thesis projects or special studies.

Plasma Electronics Facilities
Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art table top 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 CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focussable to 10^-6 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,
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). The laboratory facilities are available to faculty, staff, and graduate students for their research.

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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 speech 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 FIS, 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 Itho, 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

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 stability margins, 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 accelerators for 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

* 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 systems 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

Vwan 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 nanoelectronics 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, queuing 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. Staats, Ph.D. (UCLA, 1967)  
Quantum electronics: I.R. lasers and nonlinear optics; 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

Kung Yao, Ph.D. (Princeton, 1965)  
Optimal control, stochastic control, nonlinear filtering, estimation theory, guidance and navigation

Circuit theory, network design, filters, RC-active circuits

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

Donald M. Wiberg, Ph.D. (Cal Tech, 1965)  
Identification and control, especially of aerospace, mechanical, and nuclear processes, modeling and simulation of respiratory and cardiovascular systems

Jason C.S. Woo, Ph.D. (Stanford, 1987)  
Solid-state technology, CMOS and bipolar devices/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 networks, circuits 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

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

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)  
Computer architecture and microarchitecture design and evaluation, compiler technology for low power and high performance

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)  
Computer architecture and microarchitecture design and evaluation, compiler technology for low power and high performance

Lien Vanderberghe, Ph.D. (Katholieke U., Leuven, Belgium, 1992)  
Optimization in engineering and applications in systems and control, circuit design, and signal processing
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 interest 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
Nicoaos 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. Grelling, Ph.D. (Michican, 1970)
Solid-state microwave/millimeter wave devices and ICs
Brian H. Koiner, Ph.D. (Stanford, 1985)
Ultrasound 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. Iff, 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. Beeman (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 theorems, capacitors and inductors, duality, first-order circuits, step response, second-order circuits, natural response, forced response. Letter grading. Mr. Fetterman, Mr. Pan (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, transmisson lines and Smith chart, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading. Mr. Rahmat-Samii (F, W)


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 23. 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. Jacobsen, 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, Kirchhoff’s laws, operational amplifiers, node and loop analysis, Thevenin and Norton theorems, 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)


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. Razavi (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)
structures, interrupts, DMA), performance evaluation, (caches, main memory, virtual memory) organization

Computer Science 111. Computer system organization course M116L or Computer Science M152A, Com-
hours. Requisites: course M16 or Computer Science M51A. Hands-on design, implementation, and debugging of digital log-
ic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmed array logic, de-
 projects. Letter grading.

M. Mangione-Smith (F,W,Sp)

M116L. Introductory Digital Design Laboratory. (Same as Computer Science M152A.) Labarato-
ry, four hours; discussion, two hours. Requisites: course M16 or Computer Science M51A. Hands-on de-
ger functions. Fabrication of semiconductor devices. Letter grading.

Mr. Viswathan (F,W)

121B. Fundamentals 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. Woon (W,Sp)

122AL. Semiconductor Devices Laboratory. (5) Lecture, four hours; laboratory, four hours; outside study, seven hours. Requisites: courses 121A, 121B (may be taken concurrently). Design fabrication and characterization of p-n junction and transistors. Stu-
dents perform various processing tasks such as wa-

Mr. Chang, Mr. Fettetman (W,Sp)

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 121A. An introduction to solid-state physics, band theory, and semiconductor properties. Letter grading.

Mr. Fettetman, Mr. Yablonovitch (F)

123B. Fundamentals of Solid-State II. (4) Lecture, three hours; discussion, one hour. Requisite: course 123A. A discussion of solid-state properties, lattice vibrations, thermal properties, dielectric, mag-
etic, and superconducting properties. Letter graded.

Mr. Brown, Mr. Stafudd (W)

124. Semiconductor Physical Electronics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 123A. Band structure, semiconductor models of basic band structure parameters, statistics of carri-
ers, 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 De-
sign. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 121A, 121B. In-depth study of integrated circuit processing and device design. Device struc-
ture optimization tool is based on PISCES; process integration tool is based on SUPREM. Course famili-
ar with students in the tools. Using CAD tools, a CMOS process integration to be designed. Letter grading.

Mr. Woon (Sp)

131A. Probability. (4) Lecture, four hours; discus-
sion, one hour; outside study, ten hours. Requisites: courses 102, Mathematics 32A, 32B. Introduction to basic concepts of probability, including random vari-
ables and vectors, distributions and densities, mo-
ment-generation 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,Sp)

131B. Introduction to Statistical Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Introduction to concepts of stochas-
tic processes, emphasizing continuous- and dis-
crete-time stationary processes, correlation functions and spectral density, linear transformation, and mean-square estimation. Applications to communica-
tion, control, and signal processing. Introduction to computer simulation and analysis of stochastic pro-
cesses. 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, Mathematics 32A, 32B. Introduction to communication systems in presence of noise. Letter grading.

Mr. Fitz, Mr. Wessel (W,Sp)

132B. Data Communications and Telecommuni-
cation Networks. (4) Lecture, four hours; discus-
sion, one hour; outside study, seven hours. Requisite: course 131A. Layered communications architectures. Queuing system modeling and analysis. Error con-
trol, flow and congestion control. Packet switching, circuit switching, and routing. Network performance analysis and design. Multiple-access communica-
tions: TDMA, FDMA, polling, random access. Local, metropolitan, and wide area, integrated networks net-
works. 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, con-
jugate gradient, and quasi-Newton methods. Rates of convergence. Methods for constrained minimization: introduction to linear programming and gradient pro-
jection methods. Lagrange methods. Students ex-
pected to use HSSEASnet computers. Letter grad-
ing.

Mr. Jacobsen, Mr. Vandenbergh (W)

141. Principles of Feedback Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102. Mathematical mod-
eling of physical control systems in form of differential equations and transfer functions. Design problems, system performance indices of feedback control sys-
tems via classical techniques, root-locus and fre-

Mr. Levan, Mr. P.K.C. Wang (W,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 design and synthe-
sis, 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. Multidi-

150D. Photonic Sensor Design Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, eight hours. Limited to seniors. Multidi-

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, two hours; outside study, eight hours. Requisite: 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 basic set of 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. Requisite: courses 115A, 115B. Microelectromechanical systems design, combining lecture and laboratory instruction on micromachining 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 (Fall), Mr. Rahman-Samir (Spring)

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 and transmission lines, antennas, atmospheric, etc.). Cell-site and mobile anten nas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Liu, Mr. Stafsudd (Winter, Spring)

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 (Winter)

163B. Microwave and Millimeter Wave Active Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: 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 (Spring)

163C. Active Microwave Circuits. (4) Lecture, three hours; outside study, nine hours. Requisite: courses 115A, 151. Theory and design of microwave transistor amplifiers and oscillators; stability, noise, distortion. Letter grading. Mr. Itoh (F)

164AL. Microwave Wireless Laboratory A (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, waveometers, slotted lines, directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip, waveguide, coaxial, and stripline systems. Letter grading. Mr. Itoh, Mr. Jalali (Winter)

164DL. Microwave Wireless Laboratory II (2) (Formerly numbered 164BL.) Lecture, one hour; laboratory, two hours; outside study, six hours. Requisite: course 161. Microwave integrated circuit design from a wireless system perspective, with focus on (1) use of design tools and CAD systems, (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 (Spring)

171L. 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 116L, 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 set-ups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PC's, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem and terminal characteristics, and interfaces. Letter grading. Mr. Fetterman (Spring)

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 and laser oscillation and amplification, cw and pulsed lasers. Letter grading. Mr. Joshi, Mr. Stafsudd (Fall, Spring)

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 (Fall, Spring)

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 (Fall, Spring)

173DL. Photonics and Communication Design Laboratory. (4) (Formerly numbered 173L.) Laboratory, four hours; outside study, eight hours. Requisite: course 123A. 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 (Winter)

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 (Spring)

175. Fourier Optics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: courses 102, 121A. Two-dimensional linear systems and Fourier transforms. Introduction to 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 applications of laser radiation to be related to each example. Letter grading. Mr. Fetterman (Winter, even years)

M185. Introduction to Plasma Electronics. (4) (Same as Physics M122.) Lecture, three hours. Requisite: course 101. Study of senior-level introductory course on electronics 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 (Fall, even years)

190D. Systems Design. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Requisite: 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 (Fall, Spring)

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 form with consent of instructor and departmental 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 engineering laboratory course. Students may take additional 199 courses, but they may not be applied toward degree. Letter grading. (Fall, Winter, Spring, Summer)

Graduate Courses

201A. VLSI Architectures and Design Methodologies. (4) Lecture, four hours; outside study, eight hours. Requisite: course M216A or Computer Science M259A. 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. Mr. S. Verbeek (Fall, Spring)

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, algorithmic synthesis, and real-time issues in embedded systems. Topics include behavioral synthesis, hardware/software code-sign, 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 (Fall)

204A. Advanced Compilers. (4) Lecture, four hours; outside study, eight hours. Requisite: Computer Science 132, 252. Designed for graduate computer science and electrical engineering students. Efficient allocation of shared resources (bus, function units, register files) is one of most important areas of research in compiler architecture and compilation research. Consideration of instruction selection and scheduling, register assignment, and low-level transformation in context of contemporary computer architectures (superscalar, VLIW, and most DSP). Topics include mapping to specific inproprocessor communications buses, making effective use of hardware caches, and targeting specialized purpose function units. Letter grading. Mr. Mangione-Smith (Winter)
208A. 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 network architecture, mobile IP, wireless TCP, middleware and operating system issues, and context-aware adaptive applications. Letter grading. Mr. Srivastava (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


211A. Digital Image Processing I. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Preparation: computer programming experience. Requisite: course 113. Fundamentals of digital image processing theory and techniques. Topics include two-dimensional linear system theory, image transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading. Mr. Villasenor (F)

211B. Digital Image Processing II. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Requisite: course 211A. Advanced digital image processing theory and techniques. Topics include modeling, restoration, still-frame and video image compression, tomographic imaging, and multi-resolution analysis using wavelet transforms. Letter grading. Mr. Villasenor


212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; laboratory, four hours; outside study, seven hours. Requisite: course 212A. Multifidelity systems — polyphase representation; multistage implementations; applications of multirate systems; maximally decimated 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)

214A. 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 (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 integrat-ed 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 115G, M216A. Analysis and comparison of modern logic families (CMOS, bipolar, BICMOS, GaAs). MSI digital circuits (flip-flops, registers, counters, PLAs), VLSI memories (ROM, RAM, CCD, bubble memories, EPROM, EEPROM) and VLSI systems. Letter grading. Ms. Verbaughwe (W or Sp)

215C. Analysis and Design of RF Circuits and Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 115G, M216A. Analysis of RF circuit and system design, with emphasis on monolithic implementation in VLSI technologies. Basic concepts, communications background, transceiver architectures, low-noise and oscillator design, 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 115G, M216A. Design of synchronization and communication for VLSI circuits. Use of both digital and analog design techniques to improve data rate of electronics between fundamental building blocks, such as 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)

216A. 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 applications 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)

216B-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: S/U or letter grading. Mr. Jain, Mr. Mangione-Smith

217. Biomedical Imaging. (4) (Formerly numbered 217.) (Same as Biomedical Engineering M217.) Lecture, three hours; laboratory, four 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

219B. 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.etterman, Mr. Pan (W)

222. Integrated Circuits Fabrication Processes. (4)
Lecture, four hours; outside study, eight hours. Requisite: courses 219A, 221A. Technologies and processes of integrated circuits fabrication processes. Technological limitations of integrated circuits design. Topics include bulk crystal and epitaxial growth, thermal oxidation, diffusion, ion-implantation, chemical vapor deposition, dry etching, lithography, and metallization. Introduction of advanced process simulation tools. Letter grading.
Mr. Chang, Mr. Woo (Sp, odd years)

223. Solid-State Electronics I. (4)
Lecture, four hours; outside study, eight hours. Requisites: courses 124, 270. Energy band theory, electronic band structure of various elementary compound, and alloy semiconductors, defects in semiconductors. Recombination mechanisms, transport properties. Letter grading.
Mr. Fetterman, Mr. Pan (F)

224. Solid-State Electronics II. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 223. Thermodynamic principles and quantum mechanics of solid-state systems; 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 calculating electronic 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. Letter grading.
Mr. Yao (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 characteristics by analytical and simulation methods; mean square (MS) and maximum likelihood (ML) estimations and algorithms; detection under noise, 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 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 230B. Introduction to the design 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, NT, 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. Potte, Mr. Wesel (F)

231B. Pattern Recognition. (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 231A. 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. Rubi (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-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 design problems which may be formulated as flow problems in capacitated (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. Roychoudhury, Mr. Rubin (W)

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)
Mr. Jacobsen, Mr. Vandenberghe (F)

236B. Nonlinear Programming. (4)
Mr. Jacobsen, Mr. Vandenberghe (W)

236C. Optimization Methods for Large-Scale Systems. (4)
Mr. Roychoudhury (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; project/production management; computer science; economic models; reliability; and stochastic processes. Letter grading. Letter grading.


M259S. Seminar: Microelectromechanical Systems. (2) Seminar, two hours; outside study, four hours. Seminar on microelectromechanical systems (MEMS). Letter grading.


M274. Fiber Optic System Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 172L 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 optic transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-aided design. Architectural-level design of fiber optic transceiver circuits, including practical, quantizer, optical modulator, and electronic driver, and predistortion circuits. Letter grading. Letter grading. Letter grading.


Mr. Paganini (F)


Mr. Judy, Mr. Mr. Kaiser (F)

259S. Seminar: Microelectromechanical Systems. (2) Seminar, two hours; outside study, four hours. Seminar on microelectromechanical systems (MEMS). Letter grading.

Mr. Judy


Mr. Judy

261. Microwave and Millimeter Wave Circuits. (4) Lecture, four hours; outside study, eight hours. Requisite: course 163A. Rectangular and circular waveguides, microstrip, stripline, fine line, and dielectric waveguide 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)


Mr. Rahmat-Samii (F)
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, magnetic 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)


296. Seminar: Research Topics in Electrical Engineering. (2 to 4) 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. 
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.

M597A. 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.

M597B. Preparation for Ph.D. Preliminary Examinations. (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.

M597C. 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.


M599. Research 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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King-Ning Tu, Ph.D., Chair
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.
Mark S. Goorsky, 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 Clement, 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.
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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 100, 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 metalurgy, 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,
Students in Professor Dunn’s laboratory investigating the preparation and properties of materials.
Upper Division Courses


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 of thin sections, microscopy; electron optical, reflective modes; chemical analysis; electron optics of both instruments. Letter grading.

Mr. Arrell (W)


Mr. Dunn (W)


Mr. Dunn (Sp)

121L. Materials Science of Semiconductors Laboratory (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Requisite: 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)


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)


Mr. Tu (W)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory (2) Laboratory, four 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)


Mr. Ono (Sp)

143A. Mechanical Behavior of Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143A. Introduction to materials. 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. Przygoda (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, rubbery polymers, elastomers, adhesives. Fiber forming polymers, polymer processing technology, plastication. Letter grading.

Mr. J-M. Yang (W)


Mr. Ono (Sp)

160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading.

Mr. Dunn (F)


Mr. Dunn (W, even years)


Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 14, Electrical Engineering 108, and Physics of Electronic Materials (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 management, treatment, and serviceability emphasized as part of successful design. Letter grading.

Mr. Przygoda (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. Letter grading.

Mr. Dunn (W)

197. Seminar: Technical Writing for Materials Engineers. (2) Seminar, two hours; outside study, four hours. Letter grading. 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


Mr. Dunn (F)


Mr. Arrell (Sp)


Mr. Goorsky (Sp)
222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Prerequisites: 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. Prerequisites: 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


Mr. Gillis, Mr. Goorsky (W)

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Prerequisite: 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. Prerequisite: 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. Prerequisite: 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 microscropy, laboratory applications of contrast theory. Letter grading.

Mr. Ardell (Sp, odd years)

245C. Diffraction Methods in Science of Materials. (4) Lecture, four hours; outside study, eight hours. Prerequisite: 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. Prerequisite: 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. Prerequisite: 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 (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. Prerequisite: course 151. Mechanical properties 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)


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. Preparation: courses 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.
Mechanical and Aerospace Engineering

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Nasr M. Ghoniem, Ph.D., Vice Chair
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Professors
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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.
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Peretz P. Friedman, 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
Ravnessh 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 Gourmon 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 hydraulic topics. 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 29, 102, 103, M105A, 105D, 157, 192A


3. Sixteen technical elective units (which should contain enough design units to satisfy the overall pro-
program requirement of at least 24 design units) selected from Mechanical and Aerospace Engineering 131A, 131AL, 132A, 133A, 133AL, 150C (heat and mass transfer, thermodynamics, combustion/propulsion); 153A (acoustics); 155, 163A, 169A (unless taken as part of the core), 171B, Civil and Environmental Engineering 137L, Electrical Engineering 142 (dynamics and control); Mechanical and Aerospace Engineering 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
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:
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, M16D, M16L, 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 majors:

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, 195.

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, 227B, 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**

**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 aerelasticity, 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 simu-
lation, 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 research 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 andThermoelectrics Laboratory (Nano-HTTL) is equipped with a scanning probe microscope (atomic force, scanning tunneling, scanning thermal, and scanning laser), infrared microscope with 4nm resolution, gas and solid-state lasers (argon, T-Sapphire, and semiconductor lasers) and optical systems, vacuum systems, flow systems for low- to high-temperature property measurement (4K-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 magnetoostrictive 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 audiovisial 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.
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.

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**Faculty Areas of Thesis Guidance**

**Professors**

Mohamed A. Abdou, Ph.D. (Wisconsin, 1973)
- Fusion, nuclear, and mechanical engineering design, testing, and system analysis; thermodynamics; 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 aerelasticity, structural dynamics and unsteady aerodynamics

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
- Electromagnetoelasticity models, fatigue characterization of piezoelectric ceramics, magnetostriuctive 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 Cattan, Ph.D. (UCLA, 1966)

Heat transfer in fluid mechanics, transport phenomena in porous media, nucleoecnic 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 hydraulic of reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling


Mobile Internet, web-based product design, wireless and collaborative engineering, CAD/visualization

Nasr M. Ghoniem, Ph.D. (Wisconsin, 1977)

Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

James S. Gibson, Ph.D. (U. Texas, Austin, 1975)

Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Vijay Gupta, Ph.D. (MIT, 1989)

Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure 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, nanoelectromechanical/nanoelectromechanical systems, direct handling of macromolecules, bionano technologies, DNA-based micro sensors

Ann R. Karagözian, 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


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. Lavin, 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, 1999)

Nanoscale biomedical systems, microrobots, 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 mechanical/electrical systems; optimal and adaptive control of dynamical systems; geometric control

Owen I. Smith, Ph.D. (UC Berkeley, 1977)

Combustion and combustion-generated air pollutants, hydrometallurgy and chemical kinetics of combustion systems, semiconductors, 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 dynamical 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 transonic and 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

Pezzati F. Friedmann, Sr. 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,其中包括大型结构系统、设计和分析的航空航天结构、稳定性在自适应系统

Cornelius T. Leondes, Ph.D. (Pennsylvania, 1964)

Applied dynamic systems control

Michel A. Melkanooff, 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. Monkowitz, 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 heat transfer, environmental design, thermal and luminous engineering systems

David Okrent, Ph.D. (Harvard, 1951)

Fast reactors, reactor physics, nuclear reactor safety, 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

Ravinesh 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
Lower Division Courses


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 (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, alternate years)

Upper Division Courses

102. Mechanics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 32B, 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,Sp)

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, one hour; 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,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,Sp)

M105D. Transport Phenomena. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103, M105A, Mathematics 32B, 33A. Transport phenomena; heat conduc- tion, mass species diffusion, convective heat and mass transfer, and radiation. Engineering applica- tions in thermal and environmental control. Letter grading. Ms. Lavine (F,Sp)


131AL. Thermodynamics and Heat Transfer Labo- ratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 131A, 157. Experimen- tal study of physical phenomena and engineer- ing systems using modern data acquisition and pro- cessing techniques. Experiments include studies of heat transfer phenomena and testing of a cooling tower, heat exchanger, and internal combustion en- gine. Students take and analyze data and discuss physical phenomena. Letter grading.

Mr. Mills (F, alternate years)


Mr. Mills (W, alternate years)


Mr. Dhir (F,Sp)

133AL. Power Conversion Thermodynamics Lab- oratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 133A, 157. Experimen- tal study of power conversion and heat transfer systems using state-of-the-art plant process instru- mentation and equipment. Experiments include studies of thermodynamic operating characteristics of an actual Brayton cycle, Rankine cycle, compressive re- frigeration unit, and absorption refrigeration unit. Let- ter 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; dis- cussion, two hours; outside study, six hours. De- signed for seniors. This course is designed to provide an understanding of the design of nuclear and other power systems, power generation, power removal, power cycle, thermal hydraulic compo- nent design, overall plant design, steady state and transient operation. Letter grading.

Mr. Dhir (W)

CM140. Introduction to Biomechanics. (4) (For- merly numbered M140.) (Same as Biomedical Engineering CM140.) Lecture, four hours; outside study, eight hours. Requisites: courses 102 or (Civil Engi- neering 106B). Introduction to functional mech- anics of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and ki- nematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simula- tions and tests. Concurrently scheduled with course CM240. Letter grading.

Mr. Gupta, Mr. Kaba (W)


150B. Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 150A. Advanced aspects of potential flow theory. In- compressible flow around thin airfoils (C ρ), and wings (lilt, induced drag). Gas dynamics: oblique shocks, Prandtl/Meyer expansion and sub- sonic and supersonic flow around thin airfoils and wings. Wave drag, Transonic flow. Letter grading.

Mr. Zhong (Sp)


Ms. Karagozian, Mr. Smith (W)

150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A, 105D. Rocket propulsion con- cepts, 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 technolo- gies. Letter grading.

Ms. Karagozian (Sp)

153A. Engineering Acoustics. (4) Lecture, four hours; outside study, eight hours. Designed for junior/ senior engineering majors. Fundamental course in acoustics; propagation of sound; sources of sound. Design of field measurements. Estimation of jet and blade noise with design aspects. Letter grading.

Mr. Meecham (Sp, alternate years)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; outside study, eight hours. Requisites: course 154S. Classical preliminary design of an air- craft, including weight estimation, performance and stabili- ty, and control consideration. Term assignment consists of preliminary design of a fighter aircraft. Letter grading.

Mr. Bendiksen (W)


Mr. Bendiksen (Sp)

154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Aircraft per- formance, flight mechanics, stability, and control; some basic ingredients needed for design of an air- craft. Effects of airplane flexibility on stability deriva- tives. 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 princi- ples; 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)


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. Lab. Mr. Ghoniem, Mr. Mills (FW,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. Higo (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).


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 group responsible primarily for a subsystem and for integration with the whole. Letter grading. Mr. Endresen (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. Dirw (W).


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 mechanical design 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 (FW).

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. Tao (Sp).

162M. Senior Mechanical Engineering Design. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 134A, 134B, 136B, 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). Letter grading. Mr. Tao (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. Tao (F).

165A. Analysis of Flight Structures. (4) Lecture, four hours; laboratory, one hour; outside study, eight hours. Requisite: course 192A. 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 cylinders; 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. Atturi (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. Atturi (F).

166D. 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: minimizing, term projects used in FEM computer codes. Letter grading. Mr. Atturi, Mr. Carman (Sp).


171A. Introduction to Feedback and Control Systems. (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. M’Closkey (W).


172. Control System Design Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisite: course 117A. Application of frequency domain design techniques for control of mechanical systems. Successful control design requires a rationale 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 gyro scope, 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, moments, quotient and composition of random variables, reliability, redundancy, complex systems, stress-strength models, failure tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading. Mr. Dirw (F).

M180L. Introduction to Micromachining and Micromechanical Systems Laboratory. (4) (Formerly numbered 180L.) (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 basic MEMS structures in hands-on micromachining laboratory. Letter grading. Mr. C.-J. Kim (F).

191A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Requisites: course 192A. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transform: properties, convolution, inversion; Fourier transforms: properties, convolution; applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. Ghoniem (W).


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


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)


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, electrons, 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)

232A. 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 solutions for laminar flows; solution procedures for turbulent flows. Multicomponent diffusion. Application to hydrospheric boundary layer, ablation and transpiration, cooling of photovoltaic cells. 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


237D. Fusion Engineering and Design. (4) Lecture, four hours; outside study, eight hours. 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. 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.

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. Underlying physics and mathematics of boiling. Phenomenological theories of turbulent heat and mass transport. Letter grading. Mr. Catton

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. Underlying physics and mathematics of boiling. Phenomenological theories of turbulent heat and mass transport. Letter grading. Mr. Catton

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. Underlying physics and mathematics of boiling. Phenomenological theories of turbulent heat and mass transport. Letter grading. Mr. Catton

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 biomechanical 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. Gupte, Mr. Kabo (W)
250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Corequisite: course 192A. Development and application of fundamental principles of fluid mechanics at graduate level, with emphasis on incompressible flow. Fluid dynamics, 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 viscous 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; outside study, 150A, 150B. 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 unstable 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 250C. Development of statistical methods of wide utility in engineering applied to turbulent flows. Topics include stochastic processes, kinematics of turbulence, energy decay, Kolmogorov and Von Karman, analytical theories, and origins of Reynolds stress. Letter grading. 

Mr. Meecham (Sp)


Mr. Karagozian (F, odd years)

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250C. 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 in fluids and solids. Letter grading. 

Mr. Meecham


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)

256A. Mechanics of Deformable Solids. (4) (Formerly numbered 256A.) (Same as Civil Engineering M250A.) 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)

256B. Elasticity. (4) (Same as Civil Engineering M250B.) Lecture, four hours; outside study, eight hours. Requisite: course 256A. Linear and finite and infinitesimal strains; 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)


Mr. Atluri (Sp)


Mr. Gupta (Sp)

257A. Elastodynamics. (4) (Same as Earth and Space Sciences M224A.) Lecture, four hours; outside study, eight hours. Requisites: courses 256A, 256B. 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, non-destructive 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. 


Mr. Bendiksen (F)


Mr. Alturi (W)
262. Mechanics of Intelligent Material Systems. (4) Lecture; four hours; outside study, eight hours. Recommended: course 156B. Recommended course 266C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micromechanical analysis, including classical mechanics, micromechanical models, material 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 systems; multi-axis computer-controlled machines; machine kinematics and dynamics; multi-axis 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 252B. Modeling, dynamics, and stability of spacecraft: spinning and dual-spin spacecraft dynamics through resonance, spinning rocket dynamics; environmental torques in space, modeling and model reduction of flexible space structures. Letter grading. Mr. Yang (W)

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, multi-body dynamics, trajectory planning, motion optimization, dynamic performance and manipulator design, kinematic redundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading. Mr. 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 253A. Synthesis of structural systems; analysis and design as optimization problems; techniques for synthesis and optimization; application to aerospace and civil structures. Letter grading. Mr. Benderkisen, Mr. Felton (W)

M268B. 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. Alfini (W)

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. Benderkisen (Sp, alternate years)

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. Benderkisen (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, 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. Benderkisen (F, alternate years)

M270A. Linear Dynamic Systems. (4) (Formerly numbered 270A.) Course M270A 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)

M270B. 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, observability, and detectability. Letter grading. Mr. Gibson (F)

M270C. Linear Dynamical Systems. (4) (Formerly numbered 270C.) (Same as Chemical Engineering M280C and Electrical Engineering M240C.) Lecture; four hours; outside study, eight hours. Requisite: course 270B. Application of variational methods, Pontryagin maximum principle, Hamiltonian/Jacobi/Bellman equation (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. Mr. Speyer (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 (W)

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical Engineering M242A.) Lecture; four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M280A or Electrical Engineering M240A. State-space techniques for studying systems 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 approach. Letter grading. Mr. M'Closkey (Sp)

275A. System Identification. (4) Lecture; four hours; outside study, eight hours. Methods for identification of system from output/data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of continuous to time-discrete 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)


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 then characterize them. Letter grading. Mr. C-J. Kim (W)

281. Microelectronics. (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.) 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. Microfabrication and design for MEMS. 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 used to be characterized 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 of design 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. Hahn (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 micromechanics 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. Designing mechanisms for microactuators, including electrostatic, electromagnetic, thermal, and fluidic actuation. Applications of microelectromechanical systems. MEMS in product and system-level applications. Lecture, four hours; outside study, eight hours. Requisite: course 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 micromechanics fluid mechanics, heat transfer, and solid mechanics problems. 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 applications of laser microscopic fabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (thermal, 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), micro-machines for three-dimensional MEMS (microelectromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter grading. Mr. Zhang (Sp)


293. Quality Engineering in Design and Manufacturing. (4, Lecture). Four hours; outside study, eight hours. Requisite: course 174. Quality engineering course, emphasizing the role of microtransducers in the production process. Letter grading. Mr. Mal (F)

294. Computational Geometry for Design and Manufacturing. (4, Lecture). Four hours; outside study, eight hours. Requisite: course 194. Computer-aided 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)


296A. Damage and Failure of Materials in Mechanical Design. (4, Lecture). Four hours; outside study, eight hours. Requisites: course 156A, Materials Science 143A. Damage and failure of materials in mechanical design and case studies. Mechanics and physics of material imperfections: voids, dislocations, cracks, and inclusions. Statistical and deterministic design methods. Failure of plastic, fatigue, creep, and fatigue 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 transformations, transport mechanisms of heat and mass, moving interfaces and heat sources, natural convection, radiation, 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: courses 132A, 193. Thermodynamics, heat and mass transfer, principles of material processing, phase equilibria and transformations, transport mechanisms of heat and mass, moving interfaces and heat sources, natural convection, radiation, and growth of microstructure, etc. Applications with chemical vapor deposition, infiltration, etc. Letter grading. Mr. Ghoniem, Ms. Lavine (W)

298. Seminar: Engineering. (2 to 4, Seminar, to be arranged) Letter grading. Mr. Hahn (W)

596. Directed Individual or Tutorial Studies. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Petition forms to request enrollment must be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

597A. Preparation for M.S. Comprehensive Examination. (1 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 Examination. (1 to 12) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Reading and preparation for Ph.D. comprehensive examination. 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. candidate, including preliminary research on dissertation. 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. (Columbia U., 1951)
Herbert B. Nottage, Ph.D. (Case Institute of Technology, 1952)
Allen B. Rosenstein, Ph.D. (UCLA, 1958)
Bonham Spence-Campbell, E.E. (Cornell, 1939)

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)
Herbert B. Nottage, Ph.D. (Case Institute of Technology, 1952)
Allen B. Rosenstein, Ph.D. (UCLA, 1958)
Bonham Spence-Campbell, E.E. (Cornell, 1939)

Development of interdisciplinary engineering/social science teams and their use in planning and management of projects and systems

Lower Division Courses

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)

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.

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 purposes of management decision-making. Analysis of outcomes 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. (3-3-1.5) 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 of 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 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.

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 Reid, 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
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. Simulating 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://fsrce.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

### FRESHMAN YEAR

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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry</td>
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<td>Mathematics 31B — Calculus and Analytic Geometry</td>
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<tr>
<td>2nd</td>
<td>Mechanical and Aerospace Engineering 20 — FORTRAN Programming with Numerical Methods Applications</td>
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<tr>
<td>2nd</td>
<td>Physics 1A — Mechanics</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>Physics 4AL — Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>Materials Science and Engineering 14 — Science of Engineering Materials</td>
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<td>2nd</td>
<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mechanical and Aerospace Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations</td>
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<td>3rd</td>
<td>Mechanical and Aerospace Engineering 102 — Mechanics of Particles and Rigid Bodies</td>
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<td>3rd</td>
<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics</td>
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### JUNIOR YEAR

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<th>Course Title</th>
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<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>1st</td>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>1st</td>
<td>Mechanical and Aerospace Engineering 105D — Transport Phenomena</td>
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<td>2nd</td>
<td>Mechanical and Aerospace Engineering 192A — Mathematics of Engineering</td>
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<td>Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics</td>
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<td>Mechanical and Aerospace Engineering 157 — Basic Mechanical Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 169A — Introduction to Mechanical Vibrations* or Aerospace Engineering Elective‡</td>
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<td>Electrical Engineering 102 — Systems and Signals</td>
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<td>Mechanical and Aerospace Engineering 150B — Aerodynamics</td>
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<td>3rd</td>
<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems</td>
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<td>Mathematics Elective*</td>
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<td><strong>TOTAL</strong></td>
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* 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

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>Units</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<tr>
<td>Mathematics 31B — Calculus and Analytic Geometry</td>
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<tr>
<td>Physics 1A — Mechanics</td>
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<tr>
<td>HSSEAS GE Elective*</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<tr>
<td>Chemistry and Biochemistry 30A — Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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<tr>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemical Engineering 100 — Introduction to Chemical Engineering</td>
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<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory</td>
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<td>Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<tr>
<td>Chemical Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<tr>
<td>Chemistry and Biochemistry 30B/30BL — Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory</td>
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<td>Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 171 — Intermediate Inorganic Chemistry</td>
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<tr>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations</td>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemical Engineering 101A — Momentum Transfer</td>
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<tr>
<td>Chemical Engineering 109 — Mathematical Methods in Chemical Engineering</td>
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<tr>
<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<tr>
<td>Chemical Engineering 101B — Heat Transfer</td>
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<td>Chemical Engineering 102 — Chemical Engineering Thermodynamics</td>
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<td>Chemistry Elective†</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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<tr>
<td>Chemical Engineering 104A — Chemical Engineering Laboratory I</td>
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<tr>
<td>HSSEAS GE Elective*</td>
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<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemical Engineering 104B — Chemical Engineering Laboratory II</td>
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<tr>
<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<tr>
<td>Chemistry Elective†</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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<tr>
<td>Chemical Engineering Elective‡</td>
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<tr>
<td>Chemistry Elective†</td>
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**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

<table>
<thead>
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<th>Units</th>
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<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<tr>
<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<tr>
<td>Chemistry and Biochemistry 30A — Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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## SOPHOMORE YEAR

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<td>Chemical Engineering 100 — Introduction to Chemical Engineering</td>
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<td>Mathematics 32B — Calculus of Several Variables</td>
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<td>Chemical Engineering M105A — Introduction to Engineering Thermodynamics</td>
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## JUNIOR YEAR

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<tr>
<td>Chemical Engineering 101A — Momentum Transfer</td>
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<td>Chemical Engineering 109 — Mathematical Methods in Chemical Engineering</td>
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<tr>
<td>Chemistry and Biochemistry 156 — Physical Biochemistry</td>
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<td>Life Sciences 3 — Introduction to Molecular Biology</td>
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<td>Chemical Engineering 101B — Heat Transfer</td>
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<tr>
<td>Chemical Engineering 102 — Chemical Engineering Thermodynamics</td>
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<tr>
<td>Life Sciences 4 (Genetics) or Microbiology, Immunology, and Molecular Genetics 101 (Introductory Microbiology)</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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## SENIOR YEAR

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<tr>
<td>Chemical Engineering 104B — Chemical Engineering Laboratory II</td>
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<tr>
<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<tr>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<tr>
<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<tr>
<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Bioengineering Elective†</td>
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<td>Biology Elective‡</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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<td>HSSEAS GE Electives (2)*</td>
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**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

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<th>Course Description</th>
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<tr>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry</td>
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<td>Mathematics 31B — Calculus and Analytic Geometry</td>
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<td>Physics 1A — Mechanics</td>
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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Chemistry and Biochemistry 30A — Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<th>Course Description</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemical Engineering 100 — Introduction to Chemical Engineering</td>
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<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory</td>
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<td>Mathematics 32B — Calculus of Several Variables</td>
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<td>Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<td>Chemistry and Biochemistry 30B/30BL — Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory</td>
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<td>Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)</td>
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<td>Life Sciences 1 — Evolution, Ecology, and Biodiversity</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Chemical Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<td>Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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<td>Life Sciences 2 — Cells, Tissues, and Organs</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations</td>
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### JUNIOR YEAR

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<td>Chemistry and Biochemistry 156 — Physical Biochemistry</td>
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<td>Life Sciences 3 — Introduction to Molecular Biology</td>
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<td>Chemical Engineering 101B — Heat Transfer</td>
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<td>Life Sciences 4 (Genetics) or Microbiology, Immunology, and Molecular Genetics 101 (Introductory Microbiology)</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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<td>Chemical Engineering 104A — Chemical Engineering Laboratory I</td>
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### SENIOR YEAR

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<td>Chemical Engineering 104B — Chemical Engineering Laboratory II</td>
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<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<td>Biology Elective and Laboratory†</td>
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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Biomedical Engineering Elective‡</td>
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<td>3rd Quarter</td>
<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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**TOTAL**: 200 or 201

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*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

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

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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry.</td>
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<tr>
<td>2nd</td>
<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Mathematics 31B — Calculus and Analytic Geometry.</td>
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<td>Physics 1A — Mechanics</td>
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<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<td>Chemistry and Biochemistry 30A — Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Chemical Engineering 100 — Introduction to Chemical Engineering</td>
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<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory</td>
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<td>Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<td>2nd</td>
<td>Chemical Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<td>Chemistry and Biochemistry 30B/30BL — Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory</td>
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<tr>
<td>2nd</td>
<td>Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Mechanical and Aerospace Engineering 20 (FORTRAN Programming with Numerical Methods Applications)</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Chemistry and Biochemistry 171 — Intermediate Inorganic Chemistry</td>
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<td>Materials Science and Engineering 14 — Science of Engineering Materials</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations.</td>
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### JUNIOR YEAR

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<td>1st</td>
<td>Chemical Engineering 101A — Momentum Transfer</td>
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<td>Chemical Engineering 109 — Mathematical Methods in Chemical Engineering</td>
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<td>1st</td>
<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Chemical Engineering 101B — Heat Transfer</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes.</td>
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<td>Chemical Engineering 104A — Chemical Engineering Laboratory I</td>
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### SENIOR YEAR

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<tbody>
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<td>1st</td>
<td>Chemical Engineering 106 — Chemical Reaction Engineering</td>
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<td>Electrical Engineering 2 — Physics for Electrical Engineers</td>
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<td>Chemistry Elective\Semiconductor Manufacturing Engineering Elective\</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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**TOTAL 200**

*See page 22 for details.

1Chemistry 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.

2Suggested 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

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<tbody>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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#### SOPHOMORE YEAR

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<td>Mathematics 32B — Calculus of Several Variables</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>Civil and Environmental Engineering 15 — Introduction to Computing for Civil Engineers</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mechanical and Aerospace Engineering 102 — Mechanics of Particles and Rigid Bodies</td>
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<td>3rd Quarter</td>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Civil and Environmental Engineering 135A — Elementary Structural Analysis</td>
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<td>Civil and Environmental Engineering 153 — Introduction to Environmental Engineering Science</td>
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<td>Mechanical and Aerospace Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<td>2nd Quarter</td>
<td>Civil and Environmental Engineering 121 — Design of Foundations and Earth Structures</td>
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<td>Civil and Environmental Engineering 130 — Elementary Structural Mechanics</td>
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<td>Civil and Environmental Engineering 151 — Introduction to Water Resources Engineering</td>
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<td>Electrical Engineering 103 — Applied Numerical Computing</td>
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#### SENIOR YEAR

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**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

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### SOPHOMORE YEAR

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**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

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### SOPHOMORE YEAR

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### 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

**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 Energies 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

### 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 ..................................... 4
- Electrical Engineering 161 — Electromagnetic Waves ............................................ 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

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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
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### SENIOR YEAR

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<tr>
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<td>Electrical Engineering 141 — Principles of Feedback Control</td>
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<td>Electrical Engineering 161 — Electromagnetic Waves</td>
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<td>Biomedical Engineering Elective†</td>
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<td>2nd Quarter</td>
<td>Electrical Engineering 114D — Speech and Image Processing Systems Design</td>
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<td>Electrical Engineering 115A — Analog Electronic Circuits I</td>
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<td>Electrical Engineering 132A — Introduction to Communication Systems</td>
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<td>Chemistry and Biochemistry 30A — Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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**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

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<td>Computer Science 31 (introduction to Computer Science I)</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry</td>
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<tr>
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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31B — Calculus and Analytic Geometry</td>
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<td>Physics 1A — Mechanics</td>
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### SOPHOMORE YEAR

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<td>HSSEAS GE Electives (2)*</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 2 — Physics for Electrical Engineers</td>
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<td></td>
<td>Electrical Engineering 10 — Circuit Analysis I</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations</td>
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### JUNIOR YEAR

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<td>Electrical Engineering 101 — Engineering Electromagnetics</td>
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<td>Electrical Engineering 102 — Systems and Signals</td>
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<td>Electrical Engineering 103 — Applied Numerical Computing</td>
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<td>Electrical Engineering 110 — Circuit Analysis II</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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<td>Electrical Engineering 115A — Analog Electronic Circuits I</td>
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<td>Electrical Engineering M116C or Computer Science M51B — Computer Systems Architecture</td>
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<td>Electrical Engineering M116L or Computer Science M52A — Introductory Digital Design Laboratory</td>
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<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
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<td>Computer Science 111 — Operating Systems Principles</td>
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<td>Electrical Engineering 113 — Digital Signal Processing</td>
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<td>Electrical Engineering 115AL — Analog Electronics Laboratory I</td>
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<td>Electrical Engineering M116D or Computer Science M52B — Digital Design Project Laboratory</td>
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### SENIOR YEAR

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<td>Electrical Engineering 115C — Digital Electronic Circuits</td>
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<td>Electrical Engineering 31A — Probability</td>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td>Mechanical and Aerospace Engineering 192A — Mathematics of Engineering</td>
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<td>Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)</td>
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**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

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<td>Materials Science and Engineering 38 — Freshman Seminar: New Materials</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry</td>
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<td>Mathematics 31B — Calculus and Analytic Geometry</td>
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<td>Physics 1A — Mechanics</td>
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<td>3rd</td>
<td>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)</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>3rd</td>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<td>Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)</td>
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<td>Mechanical and Aerospace Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<td>Life Sciences Elective</td>
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<td>3rd</td>
<td>HSSEAS GE Elective*</td>
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<td>3rd</td>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Materials Science and Engineering 30L — Physical Measurement in Materials Engineering</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations</td>
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## JUNIOR YEAR

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<td>Materials Science and Engineering 130 — Phase Relations in Solids</td>
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<td>Mechanical and Aerospace Engineering 102 — Mechanics of Particles and Rigid Bodies</td>
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<td>Materials Science and Engineering 120 — Physics of Materials</td>
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<td>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>Materials Science and Engineering 143A — Mechanical Behavior of Materials</td>
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<td>Materials Science and Engineering 132 — Structure and Properties of Metallic Alloys</td>
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## SENIOR YEAR

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<td>Materials Science and Engineering 160 — Introduction to Ceramics and Glasses</td>
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<td>Materials Science and Engineering 150 — Introduction to Polymers</td>
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<td>Materials Science and Engineering 191L — Computer Methods and Instrumentation in Materials Science</td>
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<td>Elective†</td>
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<td>Materials Science and Engineering 161L — Laboratory in Ceramics</td>
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<td>Materials Science and Engineering 190 — Materials Selection and Engineering Design</td>
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**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

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<td>Materials Science and Engineering 38 — Freshman Seminar: New Materials</td>
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<td>Mathematics 31A — Calculus and Analytic Geometry</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Life Sciences Elective</td>
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<td><strong>3rd Quarter</strong></td>
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<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Electrical Engineering 10 — Circuit Analysis I</td>
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<td><strong>1st Quarter</strong></td>
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<td>Electrical Engineering 123A — Fundamentals of Solid-State I</td>
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<td>Materials Science and Engineering 130 — Phase Relations in Solids</td>
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<td>Electrical Engineering 2 (Physics for Electrical Engineers) or Materials Science and Engineering 120 (Physics of Materials)</td>
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<td>Electrical Engineering 101 — Engineering Electromagnetics</td>
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<td>Electrical Engineering 123B — Fundamentals of Solid-State II</td>
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<td>Materials Science and Engineering 122 — Principles of Electronic Materials Processing</td>
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<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
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<td>Materials Science and Engineering 121 — Materials Science of Semiconductors</td>
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<td>Electronic Materials Laboratory Elective</td>
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| 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

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<th>Course Title</th>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mechanical and Aerospace Engineering M105A — Introduction to Engineering Thermodynamics</td>
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<td>Mathematics 33B — Infinite Series and Differential Equations</td>
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## SOPHOMORE YEAR

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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>Mechanical and Aerospace Engineering 94 — Introduction to Computer-Aided Design and Drafting</td>
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<td>Materials Science and Engineering 14 — Science of Engineering Materials</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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## JUNIOR YEAR

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<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 105D — Transport Phenomena</td>
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<td>Mechanical and Aerospace Engineering 192A — Mathematics of Engineering</td>
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<td>Mechanical and Aerospace Engineering 157 — Basic Mechanical Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 169A — Introduction to Mechanical Vibrations</td>
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<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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<td>Mechanical and Aerospace Engineering 131A — Intermediate Heat Transfer</td>
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<td>Mechanical and Aerospace Engineering 156A — Strength of Materials</td>
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<td>Mechanical and Aerospace Engineering 193 — Introduction to Manufacturing Processes</td>
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## SENIOR YEAR

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<td>Mechanical and Aerospace Engineering 162A — Introduction to Mechanisms and Mechanical Systems</td>
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<td>Mechanical and Aerospace Engineering 162B — Mechanical Product Design</td>
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**TOTAL:** 193

*See page 22 for details.*
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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
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Summer Sessions, 1147 Murphy Hall
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http://www.admissions.ucla.edu/

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http://www.cs.ucla.edu/
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http://www.seas.ucla.edu/ms/
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http://www.mae.ucla.edu/
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