UCLA
HENRY SAMUELI SCHOOL OF ENGINEERING
AND APPLIED SCIENCE 2006-07

ANNOUNCEMENT
OCTOBER 1, 2006

UNIVERSITY OF CALIFORNIA,
LOS ANGELES
TO ALL STUDENTS:

Pursuant to the Federal Family Educational Rights and Privacy Act (FERPA), the California Information Practices Act, and the University of California Policies Applying to the Disclosure of Information from Student Records, students at UCLA have the right to (1) inspect and review records pertaining to themselves in their capacity as students, except as the right may be waived or qualified under Federal and State Laws and University Policies, (2) have withheld from disclosure, absent their prior written consent for release, personally identifiable information from their student records, except as provided by Federal and State Laws and University Policies, (3) inspect records maintained by UCLA of disclosures of personally identifiable information from their student records, (4) seek correction of their student records through a request to amend the records or, if such request is denied, through a hearing, and (5) file complaints with the U.S. Department of Education regarding alleged violations of the rights accorded them by FERPA.

UCLA, in accordance with Federal and State Laws and University Policies, has designated the following categories of personally identifiable information as "directory information" which UCLA may release and publish without the student's prior consent: name, address (local/mailing, permanent, and/or e-mail address, telephone numbers, major field of study, dates of attendance, number of course units in which enrolled, and degrees and honors received) of this "directory information" released and published may so indicate through URSA (http://www.ursa.ucla.edu). To restrict the release and publication of the additional items in the category of "directory information," complete the UCLA FERPA Restriction Request form available from Enrollment and Degree Services, 1113 Murphy Hall.

Student records which are the subject of Federal and State Laws and University Policies may be maintained in a variety of offices, including the Registrar’s Office, Office of the Dean of Students, UCLA Career Center, Graduate Division, and the offices of a student’s College or school and major department. Students are referred to the online UCLA Telephone Directory (http://www.directory.ucla.edu) which lists all the offices that may maintain student records, together with their campus address and telephone number. Students have the right to inspect their student records in any such office subject to the terms of Federal and State Laws and University Policies. Inspection of student records maintained by the Registrar’s Office is by appointment only and must be arranged three working days in advance. Call (310) 825-3801 or inquire at Academic Record Services, 1134 Murphy Hall.

A copy of the Federal and State Laws, University Policies, and the UCLA Telephone Directory may be inspected in the office of the Information Practices Coordinator, 600 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of the Dean of Students, 1206 Murphy Hall.

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

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

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## Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2006</th>
<th>Winter 2007</th>
<th>Spring 2007</th>
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</thead>
<tbody>
<tr>
<td>First day for continuing students to check URSA at</td>
<td>June 14, 2006</td>
<td>November 1, 2006</td>
<td>February 7, 2007</td>
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<tr>
<td><a href="http://www.ursa.ucla.edu">http://www.ursa.ucla.edu</a> for assigned enrollment appointments</td>
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<tr>
<td>URSA enrollment appointments begin</td>
<td>June 26</td>
<td>November 16</td>
<td>February 20</td>
</tr>
<tr>
<td>Registration fee payment deadline</td>
<td>September 20</td>
<td>December 20</td>
<td>March 20</td>
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<tr>
<td>QUARTER BEGINS</td>
<td>September 25</td>
<td>January 2, 2007</td>
<td>March 28</td>
</tr>
<tr>
<td>Instruction begins</td>
<td>September 28</td>
<td>January 8</td>
<td>April 2</td>
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<tr>
<td>Last day for undergraduates to ADD courses with per-course fee</td>
<td>October 20</td>
<td>January 26</td>
<td>April 20</td>
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<td>through URSA</td>
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<tr>
<td>Last day for undergraduates to DROP nonimpacted courses (without</td>
<td>October 27</td>
<td>February 2</td>
<td>April 27</td>
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<tr>
<td>transcript notation) with 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 (optional P/NP)</td>
<td>November 9</td>
<td>February 16</td>
<td>May 11</td>
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<tr>
<td>with per-transaction fee through URSA</td>
<td></td>
<td></td>
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<tr>
<td>Instruction ends</td>
<td>December 8</td>
<td>March 16</td>
<td>June 8</td>
</tr>
<tr>
<td>Final examinations</td>
<td>December 11-15</td>
<td>March 19-23</td>
<td>June 11-15</td>
</tr>
<tr>
<td>QUARTER ENDS</td>
<td>December 15</td>
<td>March 23</td>
<td>June 15</td>
</tr>
<tr>
<td>HSSEAS Commencement</td>
<td>—</td>
<td>—</td>
<td>June 16</td>
</tr>
<tr>
<td>Academic and administrative holidays</td>
<td>November 10</td>
<td>January 15</td>
<td>March 30</td>
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<td></td>
<td>November 23-24</td>
<td>February 19</td>
<td>May 28</td>
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<td>December 25-26</td>
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<td>December 29-</td>
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<td></td>
<td>January 1</td>
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## Admission Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2006</th>
<th>Winter 2007</th>
<th>Spring 2007</th>
</tr>
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<tbody>
<tr>
<td>Filing period for undergraduate applications (file with UC Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)</td>
<td>November 1-30, 2005</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Last day to file application for graduate admission or readmission with complete credentials and application fee, with Graduate Admissions/Student and Academic Affairs, 1255 Murphy Hall, UCLA, Los Angeles, CA 90024-1428</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
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<tr>
<td>Reentering students eligible to enroll begin to receive URSA notification letter at their mailing address</td>
<td>June 16, 2006</td>
<td>November 6</td>
<td>February 12</td>
</tr>
<tr>
<td>Last day to file Undergraduate Application for Readmission form at 1113 Murphy Hall (late applicants pay a late fee)</td>
<td>August 15</td>
<td>November 27</td>
<td>February 26</td>
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Murphy Hall.
A Message from the Dean

Since it welcomed its first engineering students more than 60 years ago, the UCLA Henry Samueli School of Engineering and Applied Science has been at the forefront of advanced interdisciplinary research. Among other notable achievements, the school is well-known as the birthplace of the Internet, for developing the first reverse-osmosis membrane for the desalination of water, and for other collaborative activities that have changed the way we interact with the world around us.

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

The UCLA School of Engineering is ideally situated to engage in interdisciplinary research and educational initiatives with others on campus and across Southern California. It benefits from proximity to the world-renowned David Geffen School of Medicine and the John E. Anderson Graduate School of Management, as well as the Los Angeles entertainment and media industries, Silicon Valley, the defense and aerospace industries, and a growing biotechnology sector.

Our newly-revised curriculum—with its emphasis on breadth of knowledge as well as depth—will prepare our students for success in meeting the ever-changing demands of the engineering profession. In addition, undergraduate student research opportunities are widely available and we encourage our students to take advantage of them.

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

Our distinguished faculty is composed of recognized experts in their fields, including 22 members of the National Academy of Engineering, and many junior faculty who are widely acclaimed for their work. Many faculty members are award-winning educators, and every faculty member, no matter how senior, teaches at least one undergraduate course each year.

We are seeking exceptional and dedicated students who share our desire to positively contribute to the engineering profession and society. I invite you to consider becoming a UCLA engineer.

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

Officers of Administration
Vijay K. Dhir, Ph.D., Professor and Dean of the Henry Samueli School of Engineering and Applied Science
Stephen E. Jacobsen, Ph.D., Professor and Associate Dean, Academic and Student Affairs
Gregory J. Pottie, Ph.D., Professor and Associate Dean, Research and Physical Resources
Mary Okino, Ed.D., Assistant Dean, Chief Financial Officer
Jason (Jingsheng) Cong, Ph.D., Professor and Chair, Computer Science Department
Timothy J. Deming, Ph.D., Professor and Chair, Bioengineering Department
Mark Goorsky, Ph.D., Professor and Chair, Materials Science and Engineering Department
Adrienne Lavine, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Vasilios I. Manousiouthakis, Ph.D., Professor and Chair, Chemical and Biomolecular Engineering Department
Ali H. Sayed, Ph.D., Professor and Chair, Electrical Engineering Department
William W-G. Yeh, Ph.D., Professor and Chair, Civil and Environmental Engineering Department

The Campus
UCLA is a large urban university situated between the city and the sea at the foot of the Santa Monica Mountains. Less than six miles from the Pacific, it is bordered by Sunset and Wilshire boulevards. As the city has grown physically and culturally, so has the campus, whose students and faculty mirror the cultural and racial diversity of today's Los Angeles. UCLA is one of the most widely respected and recognized universities in the world, and its impact on society can be felt into the far reaches of the globe. Students come from around the world to receive a UCLA education, and our alumni go on to become leaders in their fields, from elected officials to heads of international corporations.

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

UCLA is rated one of the best public research universities in the U.S. and among a handful of top U.S. research universities, public and private. Professor Norman Abrams is Acting Chancellor of UCLA. He succeeds Chancellor Albert Carnesale, the eighth chief executive in UCLA's 87-year history.

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

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

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Center for Embedded Networked Sensing (CENS) develops embedded networking systems and applies this revolutionary technology to critical scientific and social applications. Researchers in the Institute for Cell Mimetic Space Exploration (CMISE) identify, develop, promote, and commercialize nano-, bio-, and information technologies for sensing, control, and integration of complex natural and artificial systems. The Functional Engineered Nano-Architectonics Focus Center (FENA) leverages the latest advances in nanotechnology, molecular electronics, and quantum computing to extend semiconductor technology further into the realm of the nanoscale.

The Center for Scalable and Integrated Nano-Manufacturing (SINAM) transforms laboratory science into industrial applications in nanoelectronics and biomedicine, creating the next generation of nanotools and systems that will enable cost-effective nanomanufacturing. The Center for Nano-science Innovation for Defense (CNID) facilitates the rapid transition of research innovation in the nanosciences into applications for the defense sector. The Western Institute of Nanoelectronics (WIN), among the world's largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically needed innovations in semiconductor technology. Finally, the California NanoSystems Institute (CNSI)--a joint endeavor with UC Santa Barbara--develops the information, biomedical, and manufacturing technologies of the twenty-first century.

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

The school offers 29 academic and professional degree programs, including an interdisciplinary graduate degree program in biomedical engineering. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering. The undergraduate curricula leading to these degrees provide students with a solid foundation in engineering and applied science and prepare graduates for immediate practice of the profession as well as advanced studies. In addition to engineering courses, students complete about one year of study in the humanities, social sciences, and/or fine arts.

Master of Science and Ph.D. degrees are offered in Aerospace Engineering, Biomedical Engineering, Chemical Engineer-
The Engineering Profession

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

Aerospace Engineering

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

Working in a high-technology industry, aerospace engineers are generally well versed in applied mathematics and the fundamental engineering sciences, particularly fluid mechanics and thermodynamics, dynamics and control, and structural and solid mechanics. Aerospace vehicles are complex systems. Proper design and construction involves the coordinated application of technical disciplines, including aerodynamics, structural analysis and design, stability and control, aeroelasticity, performance analysis, and propulsion systems technology.

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

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

Bioengineering

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

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

Chemical Engineering

Chemical engineers use their knowledge of mathematics, physics, chemistry, and biology to meet the needs of our technological society. They design, research, develop, operate, and manage the chemical and petroleum industries and are leaders in the fields of energy and the environment, nanomaterials/ nanotechnology, systems engineering, 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, water production and treatment, and semiconductor industries. Architectural, engineering, and construction
firms employ chemical engineers for equipment and process design. It is also their mission to develop the clean and environmentally friendly technologies of the future.

Major areas of fundamental interest within chemical engineering are

1. Applied chemical kinetics, which includes the design of chemical processes and reactors and combustion systems,
2. Transport phenomena, which involves the exchange of momentum, heat, and mass across interfaces and has applications to the separation of valuable materials from mixtures, or of pollutants from gas and liquid streams,
3. Thermodynamics, which is fundamental to both separation processes and chemical reactor design,
4. Plant and process design, synthesis, optimization, simulation, and control, which provide the overall framework for integrating chemical engineering knowledge into industrial application and practice.

Civil and Environmental Engineering

Civil engineers plan, design, construct, and manage a range of physical systems, such as buildings, bridges, dams and tunnels, transportation systems, water and wastewater treatment systems, coastal and ocean engineering facilities, and environmental engineering projects, related to public works and private enterprises. Thus, civil and environmental engineering embraces activities in traditional areas and in emerging problem areas associated with modern industrial and social development. The civil engineering profession demands rigorous scientific training and a capacity for creativity and growth into developing fields. In Southern California, besides employment in civil engineering firms and governmental agencies for public works, civil engineering graduates often choose the aerospace industry for assignments based on their structural engineering background. Graduates are also qualified for positions outside engineering where their broad engineering education is a valuable asset.

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

Computer Science and Engineering

Students specializing in the computer science and engineering undergraduate program are educated in a range of computer system concepts. As a result, students at the B.S. level are qualified for employment as applications programmers, systems programmers, digital system designers, digital system marketing engineers, and project engineers. Undergraduates can major either in the computer science and engineering program or in the computer science program. Graduate degree programs in computer science prepare students for leadership positions in the computer field. In addition, they prepare graduates to deal with the most difficult problems facing the computer science field. University or college teaching generally requires the graduate degree.

Electrical Engineering

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

Manufacturing Engineering

Manufacturing engineering is an interdisciplinary field that integrates the basic knowledge of materials, design, processes, computers, and system analysis. The manufacturing engineering program is part of the Mechanical and Aerospace Engineering Department. Specialized areas are generally classified as manufacturing processes, manufacturing planning and control, and computer-aided manufacturing.

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

Coursework, independent studies, and research are offered in the manufacturing processes area. 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 after 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.
General Information

Facilities and Services

Teaching and research facilities at HSSEAS are in Boelter Hall, Engineering I, and Engineering IV, located in the south of campus. Boelter Hall houses classrooms and laboratories for undergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoasa.ucla.edu), the SEASnet computer facility (http://www.seas.ucla.edu/seasnet/), and offices of faculty and administration. The SEL/Engineering and Mathematical Sciences Library is also in Boelter Hall. Additional faculty offices and laboratories, the Shop Services Center, and the Student and Faculty Shop are in the Engineering I building.

Library Facilities

University Library System

The UCLA Library, a campuswide network of libraries serving programs of study and research in many fields, is among the top 10 ranked research libraries in the U.S. Total collections number more than 8 million volumes, and more than 79,000 serial titles are received regularly. Some 15,000 serials and databases are electronically available, and the UCLA Library Catalog is linked to the library’s homepage at http://www.library.ucla.edu.

Science and Engineering Library

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

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

The SEL collection contains over 584,000 volumes, subscriptions to almost 4,900 current serials, and over 4 million technical reports. “Questions? Ask Us” online live chat, e-mail, and in-person reference assistance is provided Monday through Friday.

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

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

Services

Instructional Computer Facility

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

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

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

Shop Services Center

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

Continuing Education

UCLA Extension

Department of Engineering, Information Systems, and Technical Management

Frank E. Burris, Ph.D., Director
William R. Goodin, Ph.D., Associate Director

The UCLA Extension (UNEX) Department of Engineering, Information Systems, and Technical Management (540 UNEX, 10995 Le Conte Avenue) provides one of the nation’s largest selections of continuing engineering education programs. A short course program of 141 annual offerings draws participants from around the world for two- to five-day intensive programs. The acclaimed Technical Management Program holds its seventy-second offering in September 2006 and seventy-third in March 2007.

The Information Systems program—offering 223 classes annually, including six certificate programs and three sequential programs in evening, day, weekend, and online formats—covers a broad range of information technologies.

Each year, the department offers 131 classes in engineering disciplines that include manufacturing engineering, electrical engineering, construction management, and PE review classes. In addition, 108 technical management offerings complement the engineering offerings. Most engineering and technical management classes are in a quarter-length, evening format. In addition, many of the technical management classes are now available online. Call (310) 825-3344 for short course programs, (310) 825-3858 for the Technical Management Program, (310) 825-4100 for information systems programs, and (310) 206-1548 for engineering or technical management classes, or fax (310) 206-2815. See http://www.uclaextension.edu.

Career Services

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

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

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

Ashe Student Health and Wellness Center

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

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

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

Office hours during the academic year are weekdays 8 a.m. to 6:30 p.m. except Friday, when service begins at 9 a.m. Patients without appointments (walk-ins) are seen on the first floor. Patients with appointments are seen on the first, second, or third floor. Physical therapy and the insurance office are on the fourth floor. Located at 221 Westwood Plaza; see http://www.studenthealth.ucla.edu.

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

Services for Students with Disabilities

The Office for Students with Disabilities (OSD) provides a wide range of academic support services to regularly enrolled students with documented permanent or temporary disabilities in compliance with Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, and University policies. Academic support services are determined for each student based on specific disability-based requirements. Services include campus orientation and accessibility, note takers, readers, sign language interpreters, Learning Disability Program, registration assistance, test-taking facilitation, special parking assistance, real-time captioning, assistive listening devices, on-campus transportation, adaptive equipment, support groups and workshops, tutorial referral, special materials, housing assistance, referral to UCLA's Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations. There is no fee for any of these services. All contacts and assistance are handled confidentially. Located at A255 Murphy Hall, voice (310) 825-1501, TDD (310) 206-6083; see http://www.osd.ucla.edu.

Fees and Financial Support

Fees and Expenses

The 2006-07 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 Community Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095, offers accommodations for students who have documented permanent or temporary disabilities in compliance with Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (ADA) of 1990. The Student Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095, can assist with on-campus housing inquiries.

The UCLA General Catalog contains living accommodations policies and information on dropping or withdrawing from housing contracts. For more information, contact the Community Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095 or visit the UCLA Residential Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095.
Information on UCLA International Students.

Rate Financial Aid Application for international students are asked to submit a separate financial aid. Continuing undergraduate international students in their residents must file the Free Application for UCLA Housing, which describes costs, locations, and eligibility for both private and UCLA-sponsored housing.

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

Financial Aid

Undergraduate Students

Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. Applications for each academic year are available in January. The priority application deadline for financial aid for the 2007-08 academic year is March 2, 2007. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA). International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

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

Scholarships

All UCLA undergraduate scholarship awards are made on a competitive basis, with consideration given to academic excellence, achievement, scholastic promise, and financial need. Scholarships are awarded to entering and continuing 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:

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

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

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

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

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

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

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

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

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.

Betsy and Alfred Ingersoll Scholarship. For a sophomore, junior, or senior in any HSSEAS major. Extracurricular activities and leadership are considered.

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

Eugene H. Kopp Scholarship. For a junior or senior in the field of electrical engineering with an interest in aviation.

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.

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

Northrop Grumman Scholarship. For a junior or senior in any HSSEAS major with a minimum 3.0 GPA. Character is considered.

Radio Club of America Scholarship. For a junior or senior studying wireless communications.

Stanton and Stockwell Scholarship. For an engineering student with financial need. Extracurricular activities and leadership are considered.

Kalpesh Vardhan Engineering Scholarship. For an undergraduate engineering student of any standing with no minimum GPA requirement. Selection based on application/essay.

George Andrew Zizicas Memorial Scholarship. For a sophomore, junior, or senior in any HSSEAS major.

For more scholarship information, see http://seasoaa.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.


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, on the web at http://www.fao.ucla.edu.

11
When graduating, transferring, withdrawing, or taking a leave of absence, UCLA students who have received campus-based loans must complete an exit interview with Student Loan Services. The exit interview is provided to help students better understand and plan for loan repayment. Failure to complete an exit interview results in a hold being placed on all university services and records. In addition, if the campus-based loans become delinquent following separation from UCLA, all university services and records will be withheld. For further information concerning loan repayment, visit the Student Loan Services Office, A227 Murphy Hall, (310) 825-9864; see http://www.loans.ucla.edu.

Work-Study Programs
Under Federal Work-Study, the federal government pays a portion of the hourly wage, and the employer contributes the balance. When possible, work is related to student educational objectives. Hourly pay rates comply with minimum wage laws and vary with the nature of the work, experience, and capabilities. Employment may be on or off campus. To be eligible, undergraduate and graduate students must demonstrate financial need and be a U.S. citizen or eligible noncitizen. Submission of the financial aid application is required.

Community Service is a component of the Federal Work-Study program. Students who secure a community service position are eligible to petition for an increase in work-study funds of up to $5,000 while at the same time reducing their Perkins and/or Stafford loan by the amount of the increase. Most community service positions are located off campus.

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

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

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

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

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

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

Graduate student researcher (GSR) appointments are awarded to students on the basis of scholastic achievement and promise as creative scholars. Appointees perform research under the supervision of a faculty member in research work. Half-time salaries (49 percent time) range from $14,628* to $28,668†, depending on experience. Full-time employment in summer and interterm breaks is possible, depending on the availability of research funds from contracts or grants.

Since a graduate student researcher appointment constitutes employment in the service of a particular faculty member who has a grant, students must take the initiative in obtaining desired positions. GSR appointments are generally awarded after one year of study at UCLA.

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2006-07 competition. Applicants should check the deadline for submitting the UCLA Application for Graduate Admission and the Fellowship Application for Entering Graduate Students with their preferred department.

Need-Based Aid
Unlike the awards above, which are based solely on merit and administered by HSSEAS, the University also provides work-study and low-interest loans based on financial need exclusively.

Need-based awards are administered by the Financial Aid Office in A129J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid. Continuing graduate students should contact the Financial Aid Office in December 2005 for information on 2006-07 application procedures.

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

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

- **AT&T Fellowships.** Supports doctoral study in electrical engineering; must be U.S. citizen or permanent resident; optional summer research at AT&T.
- **Atlantic Richfield Company (ARCO) Fellowship.** Department of Chemical and Biomolecular Engineering; supports study in chemical engineering.
- **William and Mary Beede Fellowship.** Department of Chemical Biomolecular Engineering; supports study in chemical engineering.
- **John J. and Clara C. Boelter Fellowship.** Supports study in engineering.
- **Leon and Alyne Camp Fellowship.** Department of Mechanical and Aerospace Engineering; supports study in engineering; must be U.S. citizen.
- **Deutsch Company Fellowship.** Supports engineering research on problems that aid “small business” in Southern California.
- **GTE Fellowship.** Departments of Computer Science and Electrical Engineering; supports study in computer science and electrical engineering.
- **IBM Doctoral Fellowship.** Supports doctoral study in computer science.
- **Les Knesel Scholarship Fund.** Department of Materials Science and Engineering; supports master's or doctoral students in ceramic engineering.
- **T.H. Lin Graduate Fellowship.** Department of Civil and Environmental Engineering; supports study in the area of structures.
- **Microelectronics Innovation and Computer Research Opportunities (MICRO).** Supports students in electrical engineering, computer science, and materials science and engineering with interest in microelectronics who intend to remain in California after graduation; must be U.S. citizen or permanent resident.
- **Microsoft Fellowship.** Supports doctoral study in computer science.

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* Nine-month 2004-05 salaries
† Eleven-month 2004-05 salaries
NCR Fellowship. Department of Computer Science; supports doctoral study in computer science.

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

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

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

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

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

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

Special Programs, Activities, and Awards

Center for Excellence in Engineering and Diversity

The HSSEAS Center for Excellence in Engineering and Diversity (CEED) seeks to create a community of collaborative and sustainable partnerships that increase academic opportunities for urban, disadvantaged, and underrepresented students. CEED supports students in precollege, undergraduate, and graduate science, engineering, mathematics, and technology curricula.

Precollege Outreach Programs

Science and Mathematics Achievement and Research Training for Students (SMARTS). A six-week commuter and residential summer program, SMARTS provides a diverse group of 50 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.

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 1,100 students. Advisers work as a team to deliver services that include SAT preparation. MSP prepares students for regional engineering and science competitions and provides an individual academic planning program, academic excellence workshops, CEED undergraduate mentors, field trips, and exposure to high-tech careers. The MSP goal is to increase the numbers of urban and educationally underserved students who are competitively eligible for UC admission, particularly in engineering and computer science.

Students are provided academic planning, SAT preparation, career exploration, and other services starting at the elementary school level through college. HSSEAS/CEED currently serves 15 schools in the Los Angeles Unified School District and four schools in the Inglewood Unified School District.

Undergraduate Programs

CEED currently supports some 200 underrepresented and disadvantaged engineering students. Components of the undergraduate program include

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

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

Academic Excellence Workshops (AEW). Providing an intensive mathematics/science approach to achieving mastery through collaborative learning and facilitated study groups, workshops meet twice a week for two hours and are facilitated by a Ph.D. student.

Bridge Review for Enhancing Engineering Students (BREES). Sponsored by Hewlett Packard. A 14-day intensive summer program designed to provide CEED students with the skills and knowledge to gain sufficient mastery, understanding, and problem solving skills in the core engineering courses. Current CEED students and incoming CEED transfer students take part in lectures and collaborative, problem-solving workshops facilitated by UCLA graduate students.

The UCLA/Hewlett-Packard Computer Science/Engineering Retention Project, coordinated by Professor William J. Kaiser and CEED, is an effort to improve student retention through the redesign of and integration of technology into core engineering courses. In particular, the effort utilized a HP-donated wireless mobile classroom (a

Students join together to solve a math problem at an academic excellence workshop.
wireless laptop cart) to facilitate instruction and interaction in special sessions of EE 10 and EE 115A. A joint effort between the Electrical Engineering Department and UCLA Center for the Study of Evaluation designed and assessed these special sessions to improve instructor feedback and engage students in a significantly enhanced instructional environment. Overall, the pilot effort has proved promising, and continued collaboration is in place to fully integrate the redesign into core engineering courses.

Academic Advising and Counseling. CEED counselors assist in the selection of course combinations, professors, and course loads and meet regularly with students to assess progress and discuss individual concerns.

Tutoring. Review sessions and tutoring are provided for several upper division engineering courses.

Career Development. Presentations by corporate representatives and field trips to major company locations are offered. Other services include summer and full-time job placement and assistance.

Cluster Systems. Common class sections that team students, Cluster Systems facilitate group study and successful academic excellence workshops.

Student Study Center: A two-room complex with a study area open 24 hours a day, the Student Study Center also houses academic workshop rooms and a computer room and is used for tutoring, presentations, and engineering student organizations. The center has an electronic message board for campus, student organization, and CEED activities and numerous bulletin boards for scholarships and employment opportunities.

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

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

Graduate Programs
OMEGA. The last letter in the Greek alphabet, OMEGA symbolizes the highest level of educational achievement. The organization is a partnership with engineering faculty and CEED to increase the number of UCLA CEED and other engineering undergraduates who are interested in graduate study. The OMEGA Research Program provides stipends for CEED undergraduates to conduct engineering research with engineering faculty mentors.

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

Student Organizations
UCLA 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 18th year on campus, AISES encourages American Indians to pursue careers as scientists and engineers while preserving their cultural heritage. The goal of AISES is to promote unity and cooperation and to provide a basis for the advancement of American Indians while providing financial assistance and educational opportunities. AISES devotes most of its energy to its outreach program where members conduct monthly science academies with elementary and precollege students from Indian Reservations. Serving as mentors and role models for younger students enables UCLA AISES students to further develop professionalism and responsibility while maintaining a high level of academics and increasing cultural awareness.

National Society of Black Engineers
Chartered in 1980 to respond to the shortage of blacks in science and engineering fields and to promote academic excellence among black students in these disciplines, NSBE provides academic assistance, tutoring, and study groups while sponsoring ongoing activities such as guest speakers, company tours, and participation in UCLA events such as Career Day and Engineers Week. NSBE also assists students with employment. Through the various activities sponsored by NSBE, students develop leadership and interpersonal skills while enjoying the college experience. See http://www.seas.ucla.edu/nsbe/.

Society of Latino Engineers and Scientists
Recognized as the national Chapter of the Year five times over the past ten years by the Society of Hispanic Professional Engineers (SHPE), SOLES promotes engineering as a viable career option for Latino students. SOLES is committed to the advancement of Latinos in engineering and science through endeavors to stimulate intellectual pursuit through group studying, tutoring, and peer counseling for all members. This spirit is carried into the community with active recruitment of high school students into the field of engineering.
SOLES also strives to familiarize the UCLA community with the richness and diversity of the Latino culture and the scientific accomplishments of Latinos. SOLES organizes cultural events such as Latinos in Science, Cinco de Mayo, and cosponsors the Women in Science and Engineering (WISE) Day with AISES, NSBE, and SWE. By participating in campus events such as Career Day and Engineers Week, the organization’s growing membership strives to fulfill the needs of the individual and the community. See http://www.seas.ucla.edu/soles/

Women in Engineering

Women make up about 23 percent of the undergraduate and 18 percent of HSSEAS graduate enrollment. Today’s opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a “males only” field. Women engineers are in great demand in all fields of engineering.

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

Student and Honorary Societies

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

- AIAA: American Institute of Aeronautics and Astronautics
- AICHe: American Institute of Chemical Engineers
- AISES: American Indian Science and Engineering Society
- Amateur Radio Club
- American Society of Civil Engineers
- American Society of Mechanical Engineers
- Biomedical Engineering Society
- Civil Engineering Honor Society
- Chi Epsilon
- Electrical engineering honor society
- Eta Kappa Nu
- Engineers Without Borders
- Institute of Electrical and Electronic Engineers
- Linux Users Group
- Materials Research Society
- National Society of Black Engineers
- Engineering social sorority
- Filipinos in Engineering Robotics Club
- Society of Automotive Engineers
- Society for the Advancement of Materials and Process Engineering
- Society for Biological Engineering
- Society of Latino Engineers and Scientists
- Society of Women Engineers
- Tau Beta Pi
- Engineering honor society
- Social fraternity of engineers, architects, and scientists

Student Representation

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

Prizes and Awards

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

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

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

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

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

Departmental Scholar Program

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

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

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

Official Publications

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

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

Grade Disputes

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

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

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

Nondiscrimination

The University of California, in accordance with applicable Federal and State Laws and University Policies, does not discriminate on the basis of race, color, national origin, sex, gender identity, pregnancy (including pregnancy, childbirth, and medical conditions related to pregnancy and childbirth), disability, age, medical condition (cancer-related), ancestry, marital status, citizenship, sexual orientation, or status as a Vietnam-era veteran or special disabled veteran. The University also prohibits sexual harassment. This nondiscrimination policy covers admission, access, and treatment in University programs and activities.

Inquiries regarding the University’s student-related nondiscrimination policies may be directed to the UCLA Campus Counsel, 3149 Murphy Hall, Box 951405, Los Angeles, CA 90095-1405, (310) 825-4042. Speech- and hearing-impaired persons may call TTY (310) 206-6083. Inquiries regarding nondiscrimination on the basis of disability covered by the Americans with Disabilities Act (ADA) of 1990 or Section 504 of the Rehabilitation Act of 1973 may be directed to Karen Henderson-Winge, Coordinator of ADA and 504 Compliance, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 825-7906, TTY (310) 206-3349; http://www.saonet.ucla.edu/ada.htm.

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

Harassment

Sexual Harassment

Every member of the University community should be aware that the University is strongly opposed to sexual harassment and that such behavior is prohibited both by law and by University policy. The University will respond promptly and effectively to reports of sexual harassment and will take appropriate action to prevent, correct and, if necessary, discipline behavior that violates this policy. See http://www.sexualharassment.ucla.edu.

Definitions

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

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

b. A student who is also an employee of the University makes submission to or rejection of such conduct a basis for evaluation in making academic or personnel decisions affecting an individ-
Certainly harassment, in its many forms, works against those values and often corrodes a person's sense of worth and interferes with one's ability to participate in University programs or activities. While the University is committed to the free exchange of ideas and the full protection of free expression, the University also recognizes that words can be used in such a way that they no longer express an idea, but rather injure and intimidate, thus undermining the ability of individuals to participate in the University community. The University of California Policies Applying to Campus Activities, Organizations, and Students (hereafter referred to as Policies; http://www.ucop.edu/ucophome/coordrev/ucpolicies/aos/toc.html) presently prohibit a variety of conduct by students which, in certain contexts, may be regarded as harassment or intimidation.

For example, harassing expression which is accompanied by physical abuse, threats of violence, or conduct that threatens the health or safety of any person on University property or in connection with official University functions may subject an offending student to University discipline under the provisions of Section 102.08 of the Policies. Similarly, harassing conduct, including symbolic expression, which also involves conduct resulting in damage to or destruction of any property of the University or property of others while on University premises may subject a student violator to University discipline under the provisions of Section 102.04 of the Policies.

Further, under specific circumstances described in the Universitywide Student Conduct Harassment Policy (http://www.deanofstudents.ucla.edu), students may be subject to University discipline for misconduct which may consist solely of expression. Copies of this Policy are available in the Office of the Dean of Students, 1206 Murphy Hall, or in any of the Harassment Information Centers listed below:

1. Center for Women and Men, B44 Student Activities Center, (310) 825-3945, http://www.thecenter.ucla.edu
2. Dashew Center for International Students and Scholars, 106 Bradley Hall, (310) 825-1681, http://www.intl.ucla.edu

Complaint Resolution
One of the necessary measures in our efforts to assure an atmosphere of civility and mutual respect is the establishment of procedures which provide effective informal and formal mechanisms for those who believe they have been victims of any of the above misconduct.

Many incidents of harassment and intimidation can be effectively resolved through informal means. For example, an individual may wish to confront the alleged offender immediately and firmly. An individual who chooses not to confront the alleged offender and who wishes help, advice, or information is urged to contact any of the Harassment Information Centers listed immediately above.

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

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

The Henry Samueli School of Engineering and Applied Science (HSSEAS) offers nine four-year curricula listed below (see the departmental listings for complete descriptions of the programs).

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

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

Admission

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

Students applying as freshmen must submit their applications during the November 1 through 30 filing period. Transfer applicants may apply for Fall, Winter, or Spring Quarter subject to the deadlines posted at http://www.admissions.ucla.edu. In addition, it is essential that official test scores be received no later than the date in January when the December test scores are normally reported.

Effective for students entering the University of California as freshman applicants in Fall Quarter 2006: each applicant must submit scores from an approved core test of mathematics, language arts, and writing. This requirement may be satisfied by taking either (1) the ACT Assessment plus ACT Writing Test or (2) the SAT Reasoning Test. In addition, all applicants must complete two SAT Subject Tests in two different subject areas selected from history/social science, mathematics (Mathematics Level 2 only), laboratory science, and a language other than English.

Applicants to the school are strongly encouraged to take the following SAT Subject Tests: Mathematics Level 2 and a laboratory science test (Biology E/M, Chemistry, or Physics) that is closely related to the intended major.

Fulfilling the admission requirements, however, does not assure admission to the school. Limits have had to be set for the enrollment of new undergraduate students. Thus, not every applicant who meets the minimum requirements can be admitted.

Although applicants may qualify for admission to HSSEAS in freshman standing, many students take their first two years in engineering at a community college and apply to the school at the junior level. Students who begin their college work at a California community college are expected to remain at the community college to complete the lower division requirements in chemistry, computer programming, English composition, mathematics, physics, and the recommended engineering courses before transferring to UCLA.

Admission as a Freshman

University requirements specify a minimum of three years of mathematics, including the topics covered in elementary and advanced algebra and two- and three-dimensional geometry. Additional study in mathematics, concluding with calculus or precalculus in the senior year, is strongly recommended and typical for applicants to HSSEAS.

Freshman applicants must meet the University subject, scholarship, and examination requirements described at http://www.admissions.ucla.edu.

Credit for Advanced Placement Tests

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Tests with scores of 3, 4, or 5. Students with AP Test credit may exceed the 213-unit maximum by the amount of this credit. AP Test credit for freshmen entering Fall Quarter 2006 fulfills HSSEAS requirements as indicated on the AP chart. Students who have completed 36 quarter units after high school graduation at the time of the examination receive no AP Test credit.

Admission as a Transfer Student

Admission as a junior-level transfer student is competitive. The University requires applicants to have completed a minimum of 60 transferable semester units (90 quarter units) and two transferable English courses prior to enrolling at UCLA. In addition, to be considered all applicants to HSSEAS majors must have at least a 3.2 grade-point average in their college work. Many of the majors in the school are impacted. Excellent grades, especially for courses in preparation for the major, are expected.

Completion of the required courses in preparation for the major is critical for admission. Articulation agreements between California community colleges and HSSEAS include college-specific course numbers for these requirements and can be found at http://www.assist.org. Applicants who are lacking two or more of the courses are unlikely to be admitted.

Required preparation for HSSEAS majors:

1. Mathematics, including calculus I and II, calculus III (multivariable), differential equations, and linear algebra
2. Calculus-based physics courses in mechanics, electricity and magnetism,
**Henry Samueli School of Engineering and Applied Science**  
**Advanced Placement Credit**

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

<table>
<thead>
<tr>
<th>AP Test</th>
<th>Score</th>
<th>UCLA Lower Division Units and Course Equivalents</th>
<th>Credit Allowed for University and GE Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art History</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Art, Studio</td>
<td>3, 4, or 5</td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Drawing Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Biology</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Chemistry 20A) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science</td>
<td>3, 4, or 5</td>
<td>4 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Computer Science (A Test)</td>
<td>3, 4, or 5</td>
<td>2 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science (AB Test)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Economics 2 (4 units)</td>
<td>4 units toward social analysis GE</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Economics 1 (4 excess units)</td>
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<tr>
<td></td>
<td>5</td>
<td>Economics 1 (4 units)</td>
<td>4 units toward social analysis GE</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
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<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
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<td>No application</td>
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<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>History</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
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<td></td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 6 (4 units) plus 4 excess units</td>
<td>4 units toward philosophical and linguistic analysis GE</td>
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<tr>
<td>French Literature</td>
<td>3 or 4</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 GE units plus 4 excess units</td>
<td>4 units toward literary and cultural analysis GE</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>4 units toward philosophical and linguistic analysis GE</td>
</tr>
<tr>
<td>Latin</td>
<td>8 units maximum for both tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latin Literature</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Latin 3 (4 units)</td>
<td>4 units toward literary and cultural analysis GE</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</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Latin 3 (4 units)</td>
<td>4 units toward literary and cultural analysis GE</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 6 (4 units) plus 4 excess units</td>
<td>4 units toward philosophical and linguistic analysis GE</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3 or 4</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 GE units plus 4 excess units</td>
<td>4 units toward literary and cultural analysis GE</td>
</tr>
<tr>
<td>Mathematics</td>
<td>8 units maximum for both tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td>May be applied toward Mathematics 31A</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8 excess units plus 4 units</td>
<td>4 units may be applied toward Mathematics 31A</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units</td>
<td>Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td>8 units maximum for all tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Mechanics)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Physics 1A)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Electricity and Magnetism)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Psychology 10 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Psychology 10 (4 units)</td>
<td>4 units toward social analysis GE</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>
and waves, sound, heat, optics, and modern physics

3. Chemistry, including two terms of general chemistry. The Computer Science and Engineering major requires only one term of chemistry; the Computer Science major does not require chemistry, but one term of chemistry may be applied as a life sciences course

4. Computer programming, including either Fortran, Pascal, C programming, or C++. Applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors should take C++.

5. Biology, including one year of biology only for applicants to the Bioengineering major

6. English composition courses, including one course equivalent to UCLA's English Composition 3 and a second UC-transferable English composition course

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

### Lower Division Courses in Other Departments

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

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

### Requirements for B.S. Degrees

The Henry Samueli School of Engineering and Applied Science awards B.S. degrees to students who have satisfactorily completed four-year programs in engineering studies. Students must meet three types of requirements for the Bachelor of Science degree:

1. University requirements
2. School requirements
3. Department requirements

### University Requirements

The University of California has two requirements that undergraduate students must satisfy in order to graduate: (1) Entry-Level Writing or English as a Second Language and (2) American History and Institutions. These requirements are discussed in detail in the Undergraduate Study section of the UCLA General Catalog.

### School Requirements

The Henry Samueli School of Engineering and Applied Science has four requirements that must be satisfied for the award of the degree: unit, scholarship, academic residence, and general education.

#### Unit Requirement

The minimum units allowed for HSSEAS students is between 185 and 192, depending on the program. The maximum allowed is 213 units.

After 213 quarter units, enrollment may not normally be continued in the school without special permission from the associate dean. This regulation does not apply to Departmental Scholars.

#### Scholarship Requirement

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

#### Academic Residence Requirement

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

#### General Education Requirements

General education (GE) is more than a checklist of required courses. It is a program of study that (1) reveals to students the ways that research scholars in the arts, humanities, social sciences, and natural sciences create and evaluate new knowledge, (2) introduces students to the important ideas and themes of human cultures, (3) fosters appreciation for the many perspectives and the diverse voices that may be heard in a democratic society, and (4) develops the intellectual skills that give students the dexterity they need to function in a rapidly changing world.

This entails the ability to make critical and logical assessments of information, both traditional and digital; deliver reasoned and persuasive arguments; and identify, acquire, and use the knowledge necessary to solve problems.

Students may take one HSSEAS GE course per term on a Passed/Not Passed basis if they are in good academic standing and are enrolled in at least three and one-half courses (14 units) for the term. For details on P/NP grading, see Grading in the Academic Policies section of the UCLA General Catalog or consult the Office of Academic and Student Affairs.

#### Requirements for Students Who Entered Fall Quarter 2005 and Thereafter

**Writing Requirement**

Students must complete the University's Entry-Level Writing or English as a Second
Language (ESL) requirement prior to completing the school writing requirement. Students admitted to the school are required to complete a two-term writing requirement—Writing I and Writing II. Two courses in English composition are required for graduation. Both courses must be taken for a letter grade, and students must receive grades of C or better (C—grades are not acceptable).

Writing I

The Writing I requirement must be satisfied by completing English Composition 3 or 3H with a grade of C or better (C—or a Passed grade is not acceptable) by the end of the second year of enrollment. The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement Tests in English or a combination of a score of 720 or better on the SAT II Subject Test in Writing and superior performance on the English Composition 3 Proficiency Examination.

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

Writing II

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

Ethics Requirement

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

Foundations of Knowledge

General education courses are grouped into three foundational areas: Foundations of the Arts and Humanities, Foundations of Society and Culture, and Foundations of Scientific Inquiry.

Five courses (24 units minimum) are required. One of the five courses must be a GE-approved Writing II (W) course. Courses listed in more than one category can fulfill GE requirements in only one of the cross-listed categories.

Foundations of the Arts and Humanities

Two 5-unit courses selected from two different subgroups:

- Literary and Cultural Analysis
- Philosophical and Linguistic Analysis
- Visual and Performance Arts Analysis and Practice

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

Foundations of Society and Culture

Two 5-unit courses, one from each subgroup:

- Historical Analysis
- Social Analysis

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

Foundations of Scientific Inquiry

One course (4 units minimum) from the Life Sciences subgroup supplemented by the following choices: Biomedical Engineering CM145/Chemical Engineering CM145, Chemistry and Biochemistry 153A, and Civil and Environmental Engineering M166/Environmental Health Sciences M166: Life Sciences

This requirement is automatically satisfied for Bioengineering majors, Chemical Engineering majors, and the biomedical option of the Electrical Engineering major. The requirement may be satisfied for Civil Engineering majors if students select an approved major field elective that is also a course approved under Foundations of Scientific Inquiry.

The aim of courses in this area is to ensure that students gain a fundamental understanding of how scientists formulate and answer questions about the operation of both the physical and biological world. The courses also deal with some of the most important issues, developments, and methodologies in contemporary science, addressing such topics as the origin of the universe, environmental degradation, and the encoding of the human genome. Through lectures, laboratory experiences, writing, and intensive discussions, students consider the important roles played by the laws of physics and chemistry in society, biology, Earth and environmental sciences, and astrophysics and cosmology.

Foundations Course Lists

Creating and maintaining a general education curriculum is a dynamic process; consequently, courses are frequently added to the list. For the most current list of approved courses that satisfy the Foundations of Knowledge GE plan, consult an academic counselor or see http://www.registrar.ucla.edu/ge/GE-ENGRNew06-07.pdf.

Requirements for Students Who Entered Prior to Fall Quarter 2005

For the approved list of courses, see http://www.seasoasa.ucla.edu/ge.html.

Department Requirements

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

1. Thirteen to 19 engineering major field courses (52 to 76 units), depending on curriculum followed

2. Two to six engineering core courses (8 to 24 units), depending on curriculum selected

3. Mathematics courses, ranging from 4 to 8 upper division units; see curricula in individual departments

Lists of courses approved to satisfy specific curricular requirements are available
Policies and Regulations
Degree requirements are subject to policies and regulations, including the following:

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

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

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

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

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

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

Advising
It is mandatory for all students entering undergraduate programs to have their course of study approved by an academic counselor. After the first term, curricular and career advising is accomplished on a formal basis. Students are assigned a faculty adviser in their particular specialization in their sophomore year or earlier.

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

Curricula Planning Procedure
1. Students normally follow the curriculum in effect when they enter the school. California community college transfers may also select the curriculum in the catalog in effect at the time they began their community college work in an engineering program, providing attendance has been continuous since that time.

2. HSSEAS undergraduate students following a catalog year prior to 2006-07 may use the computerized HSSEAS Academic Program Planner (APP), an interactive self-advising system that informs users if their academic programs meet the requirements for graduation. Students beginning upper division coursework in the major are required to submit an Academic Program Proposal to the Office of Academic and Student Affairs for approval by the associate dean. Students following the 2006-07 catalog year should see an academic counselor in 6426 Boelter Hall.

The student's regular faculty adviser is available to assist in planning electives and for discussions regarding career objectives. Students should discuss their elective plan with the adviser and obtain the adviser's approval.

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

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

Academic counselors in the Office of Academic and Student Affairs assist students with University procedures and answer questions related to general requirements.

Honors

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

Latin Honors
Students who have achieved scholastic distinction may be awarded the bachelor's degree with honors. Students eligible for 2006-07 University honors at graduation must have completed 90 or more units for a letter grade at the University of California and must have attained a cumulative grade-point average at graduation which places them in the top five percent of the school (GPA of 3.851 or better) for summa cum laude, the next five percent (GPA of 3.735 or better) for magna cum laude, and the next 10 percent (GPA of 3.591 or better) for cum laude. The minimum GPAs required are subject to change on an annual basis. Required GPAs in effect in the graduating year determine student eligibility.

Based on grades achieved in upper division courses, engineering students must have a 3.851 grade-point average for summa cum laude, a 3.735 for magna cum laude, and a 3.591 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field courses. To be eligible for an award, students should have completed at least 80 upper division units at the University of California.
Graduate Programs

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

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

Master of Science Degrees

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

Master of Science in Engineering Online Degree

The primary purpose of the new Master of Science in Engineering online degree program is to enable employed engineers and computer scientists to augment their technical education beyond the baccalaureate level and to enhance their value to the technical organizations in which they are employed. For further information, see http://www.engineer.ucla.edu.

Master of Engineering Degree

The Master of Engineering (M.Engr.) degree is granted to graduates of the Engineering Executive Program, a two-year work-study program consisting of graduate-level professional courses in the management of technological enterprises. For details, write to the HSSEAS Office of Academic and Student Affairs, 6426 Boelter Hall, UCLA, Box 951601, Los Angeles, CA 90095-1601, (310) 825-2514.

Engineer Degree

The Engineer (Engr.) degree is similar to the Ph.D. degree in that the program of study is built around a major and two minor fields, and the preliminary written and oral examinations are the same. However, a dissertation is not required. Unlike the Ph.D. degree, the Engineer degree does have a formal course requirement of a minimum of 15 (at least nine graduate) courses beyond the bachelor’s degree, with at least six courses in the major field (minimum of four graduate courses) and at least three in each minor field (minimum of two graduate courses in each).

Ph.D. Degrees

The Ph.D. programs prepare students for advanced study and research in the major areas of engineering and computer science. To complete the Ph.D., all candidates must fulfill the minimum requirements of the Graduate Division. Major and minor fields may have additional course and examination requirements. For further information, contact the individual departments. To remain in good academic standing, a Ph.D. student must obtain an overall grade-point average of 3.25.

Established Fields of Study for the Ph.D.

Students may propose other fields of study when the established fields do not meet their educational objectives.

Biomedical Engineering

Interdepartmental Program

Bioacoustics, speech, and hearing
Biocybernetics
Biomechanics, biomaterials, and tissue engineering
Biomedical instrumentation
Biomedical signal and image processing and bioinformatics
Medical imaging informatics
Molecular and cellular bioengineering
Neuroengineering

Chemical and Biomolecular Engineering Department

Chemical engineering

Civil and Environmental Engineering Department

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

Computer Science Department

Artificial intelligence
Computational systems biology
Computer networks
Computer science theory
Computer system architecture
Information and data management
Software systems

Electrical Engineering Department

Applied mathematics (established minor field only)
Communications and telecommunications
Control systems
Electromagnetics
Embedded computing systems
Engineering optimization/operations research
Integrated circuits and systems
Microelectromechanical systems/nano-technology (MEMS/nano)
Photonics and optoelectronics
Plasma electronics
Signal processing
Solid-state electronics

Materials Science and Engineering Department
Ceramics and ceramic processing
Electronic and optical materials
Structural materials

Mechanical and Aerospace Engineering Department
Applied mathematics (established minor field only)
Applied plasma physics (minor field only)
Dynamics
Fluid mechanics
Heat and mass transfer
Manufacturing and design
Nanoelectromechanical/microelectromechanical systems (NEMS/MEMS)
Structural and solid mechanics
Systems and control

For more information on specific research areas, contact the individual faculty member in the field that most closely matches the area of interest.

Admission

Applications for admission are invited from graduates of recognized colleges and universities. Selection is based on promise of success in the work proposed, which is judged largely on the previous college record.

Candidates whose engineering background is judged to be deficient may be required to take additional coursework which may not be applied toward the degree. The adviser helps plan a program to remedy any such deficiencies, after students arrive at UCLA.

Entering students normally are expected to have completed the B.S. degree requirements with at least a 3.0 grade-point average in all coursework taken in the junior and senior years.

Students entering the Engineer/Ph.D. program normally are expected to have completed the requirements for the master’s degree with at least a 3.25 grade-point average and to have demonstrated creative ability. Normally the M.S. degree is required for admission to the Ph.D. program. Exceptional students, however, can be admitted to the Ph.D. program without having an M.S. degree.

For information on the proficiency in English requirements for international graduate students, see Graduate Admission in the Graduate Study section of the UCLA General Catalog.

To submit a graduate application, see http://www.seasoasa.ucla.edu/adm_grad.html. From there connect to the site of the preferred department or program and go to the online graduate application.

Graduate Record Examination

Applicants to the HSSEAS graduate programs are required to take the General Test of the Graduate Record Examination (GRE). Specific information about the GRE may be obtained from the department of interest.

Obtain applications for the GRE by contacting the Educational Testing Service, P.O. Box 6000, Princeton, NJ 08541-6000; http://www.gre.org.
Departments and Programs of the School

Bioengineering

UCLA
7523 Boelter Hall
Box 951600
Los Angeles, CA 90095-1600

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

Timothy J. Deming, Ph.D., Chair

Professors
Denise Aberle, M.D.
Timothy J. Deming, Ph.D.
Warren S. Grundfest, M.D., FACS

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

Assistant Professors
Daniel T. Kamei, Ph.D.
Andrea M. Kasko, Ph.D.
Jacob J. Schmidt, Ph.D.

Adjunct Professor
Alfred Mann, M.S.

Adjunct Assistant Professor
Alex Bui, Ph.D.

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

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

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

Undergraduate Program Objectives
The goal of the bioengineering curriculum is to provide students with the fundamental scientific knowledge and engineering tools necessary for graduate study in engineering or scientific disciplines, continued education in health professional schools, or employment in industry. There are three main objectives: (1) to provide students with rigorous training in engineering and fundamental sciences, (2) to provide knowledge and experience in state-of-the-art research in bioengineering, and (3) to provide problem-solving and team-building skills to succeed in a career in bioengineering.

Undergraduate Study

Bioengineering B.S.

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

The Major
Required: Bioengineering 100, 110, 120, 165, 176, 180, 180L, 181, 181L, 182A, 182B, 182C, Chemistry and Biochemistry 153A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and two major field elective courses (8 units) from Biomedical Engineering C101, CM102, CM103, CM145, CM150, CM150L, C170, C171, CM180, C181, C185, CM186L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew06-07.pdf.

Bioengineering students participate in hands-on learning with a dissection exercise.
Faculty Areas of Thesis Guidance

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

Timothy J. Deming, Ph.D. (UC Berkeley, 1993)
Polymer synthesis, polymer processing, supramolecular materials, organometallic catalysis, biomimetic materials, polypeptides

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

Alex Bui, Ph.D. (UCLA, 2000)
Adjunct Assistant Professor

James Dunn, M.D., Ph.D. (Harvard, MIT, 1997)
Biomaterials, cell-material interactions, materials processing, tissue engineering, prosthetic and regenerative dentistry

James Dunn, M.D., Ph.D. (Harvard, MIT, 1997)

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

Assistant Professors
Daniel T. Kamei, Ph.D. (MIT, 2001)
Molecular cell bioengineering, rational design of molecular therapeutics, systems-level analyses of cellular processes, molecular modeling, quantitative cell biology

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

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

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

Upper Division Courses

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

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

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

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

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

6. Physics for Bioengineers Laboratory III. (3) (Formerly numbered 6L) Lecture, one hour; laboratory, four hours; outside study, four hours. Corequisites: course 1L or Physics 4AL. Corequisite: course 2 or Physics 1B. Continuation of introductory experimental physics laboratory course that explores basic physical concepts from biological perspective. Topics include DC and AC circuits, ion channels, electric circuit analogs in biological systems, optics of microscope, physics of light gun emission and absorption, fluorescence, laser, and biology. Letter grading.

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

110. Biomedical Intelligence Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 100, Mathematics 33B, Mechanical and Aerospace Engineering 20. Corequisite: Chemical Engineering 101A. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body, extracorporeal devices, tissue engineering systems, and biological organs. Introduction to pharmacokinetic analysis. Letter grading.


165. Bioethics and Regulatory Policies in Biomedical Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Increasing pace of biotechnological development requires intensive preparation for young scientists (i.e., graduate students, postdoctoral research fellows, and junior faculty) on issues in biomedical research and regulatory policy. Examination of role of scientists in participating in, supporting, or opposing establishment of regulatory frameworks, relationship between scientists and socio-economic development of public and private and discussion of role of scientists in public arena, academic institutions, media, and industry. May be appropriate for students who already have some knowledge and/or experience in molecular biology, genetics, or biotechnology. Letter grading.

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


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

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

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

Upper Division Courses

100. Biotechnology Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 14C or 30A, and Mathematics 32B. Fundamental basis for analysis and design of biological and biomedicale devices and systems. Clarity and statistical thermodynamic and biological concepts associated with biological phenomena. Material, energy, charge, and force balances. Introduction to network analysis. Letter grading.

110. Biomedical Transducers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 100, Mathematics 33B, Mechanical and Aerospace Engineering 20. Corequisite: Chemical Engineering 101A. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body, extracorporeal devices, tissue engineering systems, and biological organs. Introduction to pharmacokinetic analysis. Letter grading.

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

165. Bioethics and Regulatory Policies in Biomedical Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Increasing pace of biotechnological development requires intensive preparation for young scientists (i.e., graduate students, postdoctoral research fellows, and junior faculty) on issues in biomedical research and regulatory policy. Examination of role of scientists in participating in, supporting, or opposing establishment of regulatory frameworks, relationship between scientists and socio-economic development of public and private and discussion of role of scientists in public arena, academic institutions, media, and industry. May be appropriate for students who already have some knowledge and/or experience in molecular biology, genetics, or biotechnology. Letter grading.


Mr. Dunn, Mr. Wu (F)
Biomedical Engineering

Interdepartmental Program

UCLA
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(310) 794-5945
fax: (310) 794-5956
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http://www.bme.ucla.edu

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

Professors
Denise Aberle, M.D. (Bioengineering, Radiological Sciences)
Abeer A.H. Alwan, Ph.D. (Electrical Engineering)
Rajive Bagrodia, Ph.D. (Computer Science)
Francisco Bezanilla, Ph.D. (Physiology)
Arnold J. Berk, M.D. (Microbiology, Immunology, and Molecular Genetics)
Sally Blower, Ph.D. (Biomathematics)
Angelo Caputo, Ph.D. (Dentistry)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)
Tony F.C. Chan, Ph.D. (Mathematics)
Peng-Shen Chen, Ph.D., in Residence (Medicine)
Yong Chen, Ph.D. (Mechanical and Aerospace Engineering)
Marie Françoise Chesselet, M.D., Ph.D. (Neurology)
Mark Cohen, Ph.D. (Neurology, Psychiatry and Biobehavioral Sciences, Radiological Sciences)
Jean B. deKernion, M.D. (Urology)
Joseph L. Demer, M.D., Ph.D. (Neurology, Ophthalmology)
Linda L. Demer, M.D., Ph.D. (Cardiology, Physiology)
Timothy J. Deming, Ph.D. (Bioengineering)
Vijay K. Dhir, Ph.D. (Mechanical and Aerospace Engineering)
Joseph J. DiStefano III, Ph.D. (Computer Science, Medicine)
Bruce H. Dobkin, M.D. (Neurology)
Gary Duckweiler, M.D., Ph.D. (Radiological Sciences)
Bruce S. Dunn, Ph.D. (Materials Science and Engineering)
V. Reggie Edgerton, Ph.D. (Physiological Science)
Jack L. Feldman, Ph.D. (Neurobiology, Physiological Science)
Harold R. Feiterman, 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)
Alan Garfinikel, Ph.D. (Cardiology, Physiological Science)
Robin L. Garrell, Ph.D. (Chemistry and Biochemistry)
Bruce R. Gerratt, Ph.D. (Head and Neck Surgery)
Warren S. Grundfest, M.D. FACS (Bioengineering, Electrical Engineering, Surgery)
Robert P. Gunsalus, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Vijay Gupta, Ph.D. (Mechanical and Aerospace Engineering)
Chih-Ming Ho, Ph.D. (Mechanical and Aerospace Engineering, Ben Rich Lockheed Martin Professor of Aeronautics, Center for Micro Systems Director)
Edward J. Hoffman, Ph.D. (Molecular and Medical Pharmacology, Radiological Sciences)
Henry S.C. Huang, D.Sc. (Biomathematics, Molecular and Medical Pharmacology)
Stephen E. Jacobsen, Ph.D. (Electrical Engineering)
J-Woody Ju, Ph.D. (Civil and Environmental Engineering)
William J. Kaiser, Ph.D. (Electrical Engineering)
Hooshang Kangarloo, M.D. (Pediatrics, Radiological Sciences)
Patricia A. Keating, Ph.D. (Linguistics)
Chang-Jin Kim, Ph.D. (Mechanical and Aerospace Engineering)
J. John Kim, Ph.D. (Mechanical and Aerospace Engineering)
Jess F. Kraus, Ph.D., M.P.H. (Epidemiology)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
Elliot M. Landaw, M.D., Ph.D. (Biomathematics)
Andrew F. Leuchter, M.D. (Psychiatry and Biobehavioral Sciences)
James C. Liao, Ph.D. (Chemical and Biomolecular Engineering)
Jia-Ming Liu, Ph.D. (Electrical Engineering)
Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering)
Keith Markolf, Ph.D. (Orthopaedic Surgery)
Edward McCabe, M.D. (Pediatrics)
Harry McKellop, Ph.D., in Residence (Orthopaedic Surgery)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Montbouquette, Ph.D. (Chemical and Biomolecular Engineering)
Sherie L. Morrison, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Peter M. Narins, Ph.D. (Ecology and Evolutionary Biology, Physiological Science)
Stanley Nelson, M.D. (Human Genetics)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
D. Stott Parker, Jr., Ph.D. (Computer Science)
Yahya Rahmat-Samii, Ph.D. (Electrical Engineering)
Shlomo Raz, M.D. (Urology)
Vwani Roychowdhury, Ph.D. (Electrical Engineering)
Michael Sofroniew, M.D., Ph.D. (Neurobiology)
James G. Tidball, Ph.D. (Physiological Science)
Arthur Toga, Ph.D. (Neurology)
James L. Weiss, M.D. (Cardiology)
Owen N. Witte, Ph.D. (Microbiology and Molecular Genetics)
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


Electives. Computer Science 276C, Electrical Engineering 214B, Linguistics 204,
Biocybernetics

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

The program provides directed interdisciplinary biosystem studies to establish a foundation in system and information science, mathematical modeling, measurement and integrative biosystem science, as well as related specialized life sciences domain studies. It fosters careers in research and teaching in engineering, medicine, and/or the biomedical sciences, or research and development in the biomedical or pharmaceutical industry. At the system and integration level, biocybernetics methodology is quite broadly applicable to a large spectrum of biomedical problems.

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

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

Course Requirements

Biocybernetics can serve as a minor field for other Ph.D. majors if students complete the following courses with a grade-point average of B+:
- Biomedical Engineering CM186B, M296A, and one additional graduate-level elective from the additional foundations or electives list.

Core Courses (Required)

- Biomedical Engineering CM186B, C201, CM202, CM203, and either M296A or Biostatistics 220.

Electives


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

- Biomedical Engineering C201, CM202, CM203, and two courses from CM240, CM280, C281, 282, C285.

Electives


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 CM150, CM150L, C201, CM202, CM203, Mechanical and Aerospace Engineering 284.

Electives


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 correlat-
ing clinical findings with genomic markers. Graduates of the program integrate advanced digital processing and artificial intelligence technologies with healthcare activities and biomedical research. They are prepared for careers involving innovation in the fields of signal processing, medical imaging, and medical-related informatics in either industry or academia.

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

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


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

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

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

Course Requirements


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

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


Neuroengineering
The neuroengineering field is a joint endeavor between the Neuroscience Interdepartmental Ph.D. Program in the Geffen School of Medicine and the Biomedical Engineering Interdepartmental Graduate Program in HSSEAS, with the active involvement of scientists and technologies from the Jet Propulsion Laboratory (JPL). The objectives of the neuroengineering field are to enable (1) students with a background in engineering to develop and execute projects that address problems that have a neuroscience base, including locomotion and pattern generation, central control of movement, and the processing of sensory information; (2) students with a background in biological sciences to develop and execute projects that make use of state-of-the-art technology, including MEMS, signal processing, and photonics. In preparing students to use new technology, the program also introduces them to basic concepts in engineering that are applicable to the study of systems neuroscience, including signal processing, communication, and information theory; and (3) all trainees to develop the capacity for the multidisciplinary teamwork that is necessary for new scientific insights and dramatic technological progress. Courses and research projects are cosponsored by faculty members in both HSSEAS and the Brain Research Institute (BRI).

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

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

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

**Required Courses.** Biomedical Engineering M260, M263, Neuroscience M202. For MEMS emphasis, required courses are Biomedical Engineering CM150L, CM250A, M250B (course CM150L is optional if the requisite for course CM250A is met). For signal processing and information 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 neuroscience 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 CM150L; those without previous exposure to neuroscience should take Physiological Science 111A; those without previous exposure to signal processing should take Electrical Engineering 102 and 113. Both courses are offered every quarter.

**Seminars (First-Year).** Two seminars in problem-based approaches to neuroengineering are required. All first-year students attend a series of weekly research seminars that allow both students and faculty members to become more conversant with the broad range of subjects in neuroengineering. In Fall Quarter, a series called “Meet the Professors” consists of informal talks by UCLA faculty members and collaborative researchers from the surrounding area. The series introduces the faculty to the students and vice versa, and helps faculty in neuroscience and engineering discover opportunities for collaboration that engage students in the neuroengineering program. In Winter and Spring Quarters, seminar speakers are selected from commercial, academic, and government organizations.

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

**Lower Division Courses**

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

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

**Upper Division Courses**

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

CM102. Basic Human Biology for Biomedical Engineers I. (4) (Same as Physiological Science CM102.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM202. Letter grading.


CM140. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aerospace Engineering 101, 102, 156A. Introduction to mechanical functions of human body; skeletal 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.

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

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

CM150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Formerly numbered CM150.) (Same as Electrical Engineering CM150 and Mechanical and Aerospace Engineering CM180.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L; Physics 1A, 1B, 1C, 4A, 4B; Corequisite: course CM150L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250A. Letter grading.

C185. Introduction to Tissue Engineering. (4) Lecture, three hours; outside study, nine hours. Requisites: course CM102 or CM202, Chemistry 20A, 20B, 20L, Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course C285. Letter grading. Mr. Wu (Sp)

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

CM186B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered M186B.) (Same as Computational and Systems Biology M186B and Computer Science CM186BL.) Lecture, four hours; laboratory, four hours. Concurrently scheduled with course C271. Letter grading. Mr. DiStefano (W)


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/phantom tissues, making tissue phantoms, determination of optical properties of different tissues, techniques of temperature distribution measurements. Concurrently scheduled with course C270. Letter grading.


CM180. Introduction to Biomaterials. (4) (Same as Materials Science CM180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading. Mr. Wu (W)

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

C187. Applied Tissue Engineering: Clinical and Industrial Perspectives. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topical issues of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include: tissue engineering: cell source, delivery devices, FDA approval processes, and physical/chemical and biological testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue, engineered tissue, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges for tissue engineering devices. Concurrently scheduled with course C287. Letter grading. Mr. Wu (F)

M214A. Digital Speech Processing. (4) (Same as Electrical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: Electrical Engineering 114D or 211A. Mathematical models 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. Mr. Alwan (W)

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

M217. Biomedical Imaging. (4) (Same as Electrical Engineering M217.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Electrical Engineering 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, positron-emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, system configurations and their effects on reconstruction algorithms, system configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. 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 majors. Introduction to wide scope of biomedical engineering via treatment of selected important individual topics by small team of specialists. Concurrently scheduled with course C101. Letter grading. Mr. Kamei (F)

CM202. Basic Human Biology for Biomedical Engineers I. (4) (Same as Physiology Science CM202.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology; biochemistry; and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (or system) to system basis. Fundamental emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomaterial facilities. Concurrently scheduled with course CM102. Letter grading. Mr. Grundfest (F)

CM203. Basic Human Biology for Biomedical Engineers II. (4) (Same as Physiology Science CM203.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology; biochemistry; and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology, including organ systems (digestive, skin, musculoskeletal, endocrine, immune, urinary, reproductive). System-specific models/simulations (immune regulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional basis of biomedical instrumentation (dialysis, artificial skin, pathogen detectors, ultrasound, birth-control drug delivery). Concurrently scheduled with course CM102. Letter grading. Mr. Grundfest (W)

M214A. Digital Speech Processing. (4) (Same as Electrical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Electrical Engineering 114D or 211A. Mathematical models 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. Mr. Alwan (W)

C187. Applied Tissue Engineering: Clinical and Industrial Perspectives. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemical Engineering 101C and 106, or Chemistry 156. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. Letter grading. Mr. Liao (Sp)

M217. Biomedical Imaging. (4) (Same as Electrical Engineering M217.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Electrical Engineering 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, positron-emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, system configurations and their effects on reconstruction algorithms, system configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. Letter grading.
220. Introduction to Medical Informatics. (2) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to the field. Definition of this emerging field of study, current research efforts, and future directions in research. Key issues in medical informatics to expose students to different disciplines and domains, such as information system architectures, data and process modeling, information extraction and representations, information retrieval and visualization, health services research, telemedicine, bioinformatics, and image research endeavors and applications. S/U grading.

Mr. Kangarloo (F)

221. Human Anatomy and Physiology for Medical Informatics. (4) Lecture, four hours; outside study, eight hours. Corequisite: course 222. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on visualization of anatomy and physiology from imaging perspective. Topics include chest, cardiac, neurology, gastrointestinal/genitourinary, and musculoskeletal systems. Examination of basic imaging physics (magnetic resonance, computed tomography, ultrasound), concepts in image formation and processing, and clinical applications. Exposure to challenges of medical practice today and current usage of imaging, including computed tomography, magnetic resonance, and ultrasound. Concepts in image formation and processing, and clinical applications. Participation in clinical noon conferences to further broaden exposure and understanding of medical problems. S/U grading.

Mr. Kangarloo (F)

222A-223B. Programming Laboratories for Medical Informatics I, II, III. (4-4-4) Lecture, two hours; laboratory, four hours. Corequisite: course 222. Designed for graduate students. Programming laboratories to support coursework in other medical informatics core curriculum courses. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used in image processing and medical information system infrastructures (HL7, DICOM). Letter grading. 222A. Integrated with course 222B to reinforce concepts presented with practical experience. Projects focus on understanding medical networking issues and implementation of basic protocols for healthcare environment, with emphasis on use of DICOM. Requisite: course 222B. Requisite: course 222A. Integrated with courses 224A and 227 to reinforce concepts presented with practical experience. Projects focus on medical image capture and retrieval.

Mr. Meng (F, W, Sp)

222B. Advanced Imaging for Informatics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 224A. Additional modalities and current research in imaging. Topics include nuclear medicine, functional magnetic resonance imaging (fMRI), MR diffusion/perfusion, and optical imaging, with focus on image analysis and visualization tools. Basic physics principles behind these newer imaging concepts, with exposure to seminal works. Current research efforts, with focus on clinical applications and new types of information available. Geared toward nonphysicists to provide basic understanding of issues related to advanced medical image acquisition and to understand functionality of imaging databases and image models facilitating sharing of imaging data for clinical and research purposes. Letter grading.

Mr. Sinha (W)

M225. Bioseparations and Bioprocess Engineering. (4) (Same as Chemical Engineering CM225.) Lecture, three hours; discussion, one hour; outside study, five hours. Requisites: Chemical Engineering 101C and 103, or Chemistry 156. Separation strategies, unit operations, and economic factors used to design processes, with focus on problems in implementation and design of processes, with applications to bioengineering. Introduction to basic human anatomy and physiology. Geared toward nonphysicists to provide basic understanding of human anatomy and physiology concepts from other courses. Four hours per week in clinical environments, observing clinicians in different medical environments to gain appreciation of current practices, imaging, and information systems. Participation in clinical noon conferences to further broaden exposure and understanding of medical problems. S/U grading.

Mr. Sinha (Sp)

224A. Physics and Informatics of Medical Imaging. (4) Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to principles of medical imaging and imaging informatics for nonphysicists. Overview of core imaging modalities: computed radiography (CR), computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US). Emphasis on physics of image formation and image reconstruction methods. Overview of DICOM data models, basic medical image processing, content-based image retrieval, PACS, and image data management. Current research efforts, with focus on clinical applications and new types of information available. Geared toward nonphysicists to provide basic understanding of issues related to basic medical image acquisition. Letter grading.

Mr. Sinha (W)

224B. Medical Decision Making. (4) Lecture, four hours; outside study, eight hours. Requisite: course 224A. Introduction to principles of medical imaging and informatics for nonphysicists. Overview of core imaging modalities: computed radiography (CR), computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US). Emphasis on physics of image formation and image recon-struction methods. Overview of DICOM data models, basic medical image processing, content-based image retrieval, PACS, and image data management. Current research efforts, with focus on clinical applications and new types of information available. Geared toward nonphysicists to provide basic understanding of issues related to basic medical image acquisition. Letter grading.

Mr. Sinha (W)

228. Medical Decision Making. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concepts of evidence-based medicine and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluation of diagnostic and therapeutic procedures. Focus on technical advances in medical decision support systems and expert systems for decision making. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading.

Mr. Kangarloo (W)

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

Mr. Brown (F)

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

Mr. Gupta (W)

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

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

Mr. Liao (F)

M248. Introduction to Biological Imaging. (4) (Same as Chemical and Biomolecular Engineering CM248.) Lecture, three hours; laboratory, one hour; outside study, seven hours. Exploration of role of imaging in modern biology and medicine, including imaging physics and technology, image processing, and applications of imaging for a range of modalities. Practical experience provided through a series of imaging laboratories. Letter grading.
CM250A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) Formerly numbered M250A. (Same as Electrical Engineering CM250A and Mechanical and Aerospace Engineering CM280A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL, 16A, 16L, 250B. Introduction to micromachining, microelectromechanical systems and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Design methods for microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM190A. Letter grading.

M250B. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) Same as Electrical Engineering M250B and Mechanical and Aerospace Engineering M280B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course M250A. Introduction to design and fabrication of MEMS. 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.

CM250L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Electrical Engineering CM250L and Mechanical and Aerospace Engineering CM280L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisites: course CM250A. Hands-on introduction to micromachining techniques and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM150L. Letter grading.


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

M260. Neuroengineering. (4) Formerly numbered 260L. (Same as Neuroscience M260L.) Lecture, four hours; laboratory, three hours. Requisites: Mathematics 32A, 32B, 33A, 33B, Life Sciences 3, Physics 1A, 1B, 1C. Introduction to principles and technologies of neural recording and stimulation. Neurophysiology: clinical electrophysiology (EEG, evoked potentials, inverse problem, preprocessing of data); extracellular recording of extra- cellular microelectrodes and recording (field potentials and single units), chronic recording with extra- cellular electrodes; electrode biocompatibility, tissue damage, electrode and cable survival; intracellular recording and glass pipettes electrodes, iontophoresis; imaging neural activity (Ca imaging, voltage-sense- sive dyes), intrinsic optical imaging; MRI, MRT Letter grading.


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

C270L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) Laboratory, four hours; outside study, two hours. Corequisites: course C270. Introduction to experimental and computational techniques used in studying laser-tissue interactions. Topics include computer simulations of light propaga- tion in tissue, measuring absorption spectra of tissue/ tissue phantoms, making tissue phantoms, determina- tion of optical properties of different tissues, tech- niques of temperature distribution measurements. Concurrently scheduled with course C170L. Letter grading.


C280. 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 104. Engineering materials used in medicine and dentistry for repair and/or restoration of dam- aged 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.


C285. Introduction to Tissue Engineering. (4) Lecture, three hours; outside study, nine hours. Requi- sites: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerative medicine and tissue engineering. Topics include proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course CM190B. Letter grading.

C286B. Computational Systems Biology: Mod- eling and Simulation of Biological Systems. (5) (Same as Computer Science CM286B.) Lecture, four hours; laboratory, three hours. Corequisite: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/ biomedical processes and systems at multiple levels of organization. Control system, multiscale, predator-prey, pharmacokinetic (PK), pharmacody- namic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular, bio- logical (biomedical pathways/networks), organismal, and organ systems levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exer- cises in class and PC laboratory assignments. Concurrently scheduled with course CM190B. Letter grading.

C286L. Biomedical Systems/Biocytbernetics Re- search Laboratory. (2 to 4) (Formerly numbered CM296L.) (Same as Computer Science CM296L.) Laboratory, four hours. Requisite: course CM286B. Special laboratory techniques in bio- cybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Comprehensive experiment design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM186L. Letter grading.

C287. Applied Tissue Engineering: Clinical and Industrial Perspectives. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regenerative products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin and artificial skin, blood vessels, cartilage and articular tissues, peripheral nerves, blood vessels, neurotissue engineering, liver, kidney, and other organs. Clinical and industrial per- spectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engi- neering devices. Concurrently scheduled with course C181. Letter grading.

and two-dimensional cardiac tissue. Simulation on (AP). Theory of AP propagation in one-dimensional modeling and computer simulation of cardiac electrophysiology. (4) Same as Computer Science M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmaceutical, biochemical, and related systems. Control system, multicompartamental, noncompartamental, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other related data environments. Problem solving in PC laboratory. Letter grading. Mr. DiStefano (F)

M296B. Advanced Optimal Estimation and Experiment Design for Biomedical Systems. (4) Same as Biomedical Engineering M270, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course M296A or Biostatistics 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 evaluating model parameters. 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 (Sp)


M296D. Introduction to Computational Cardiology. (4) Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM188B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading. Mr. Kogan (F)

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

299. Seminar: Biomedical Engineering Topics. (2) Seminar, two hours; outside study, four hours. Designed for graduate biomedical engineering students. Seminar by leading academic and industrial biomedical engineers from UCLA, other universities, and biomedical engineering companies such as Baxter, Amgen, Medtronic, and Guidant on development and application of recent technological advances in the discipline. Exploration of cutting-edge developments and challenges in wound healing models, stem cell biology, angiogenesis, signal transduction, gene therapy, cDNA microarray technology, bioartificial cultiva-

ti, nano- and micro-hybrid devices, scaffold engineering, and bioinformatics. S/U grading. Mr. Wu (F,W,Sp)

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

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

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

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

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

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

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate biomedical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.
control/optimization/integration/synthesis, membrane science, semiconductor processing, chemical vapor deposition, plasma processing and simulation, electro-chemistry corrosion, polymer engineering, and hydrogen production.

Students are trained in the fundamental principles of these fields while learning a sensitivity to society’s needs—a crucial combination in addressing the question of how industry can grow and innovate in an era of economic, environmental, and energy constraints.

The undergraduate curriculum leads to a B.S. in Chemical Engineering, is accredited by ABET and AIChE, and includes the standard curriculum, as well as bioengineering, biomedical engineering, environmental, and semiconductor manufacturing options. The department also offers graduate courses and research leading to M.S. and Ph.D. degrees. Both graduate and undergraduate programs closely relate teaching and research to important industrial problems.

Undergraduate Mission and Program Objectives

The mission of the undergraduate program is to educate future leaders in chemical and biomolecular engineering who effectively combine their broad knowledge of mathematics, physics, chemistry, and biology with their engineering analysis and design skills for the creative solution of problems in chemical and biological technology and for the synthesis of innovative (bio)chemical processes and products. This goal is achieved by producing alumni who demonstrate (1) the ability to draw readily on a rigorous education in mathematics, physics, chemistry, and biology in addition to the fundamentals of chemical engineering to creatively solve problems in chemical and biological technology, (2) an understanding and sensitivity to social, ethical, environmental, and economical issues involving chemical engineering practice and an understanding of the role of chemical engineers in sustainable development, (3) successful participation in multidisciplinary teams assembled to tackle complex multifaceted problems that may require implementation of both experimental and computational approaches and a broad array of analytical tools, and (4) the ability to build on their undergraduate-level scientific knowledge and engineering skills through graduate study in the sciences and engineering and through success as professionals in diverse fields, including business, medicine, and environmental protection, as well as chemical and biomolecular engineering.

Undergraduate Study

Chemical Engineering B.S.

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

Chemical Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 108A, 108B, 109, Chemistry and Biochemistry 113A, 153A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and one biomedical elective course (4 units) from Chemical Engineering C115, C125, CM145 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Biomolecular Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 108A, 108B, 109, Chemistry and Biochemistry 113A, 153A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and two elective courses (8 units) from Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C125, C140.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

UHV surface analytical system.
31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104C, 104CL, 106, 107, 108A, 108B, 109, C116, Chemistry and Biochemistry 113A, 153A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and one biomolecular elective course (4 units – Chemical Engineering CM145 is recommended; another chemical engineering elective may be substituted with approval of the faculty adviser). For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Environmental Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104C, 104CL, 106, 107, 108A, 108B, 109, C116, Chemistry and Biochemistry 113A, 153A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and one elective course (4 units) from Materials Science and Engineering 104, 120, 121, 122, or 150 plus one elective course (4 units) from Electrical Engineering 2, 100, 121B, 123A, or 123B. For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Graduate Study

For information on graduate admission, see Graduate Programs, page 24. For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure. The following introductory information is based on the 2006-07 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the “Publications” link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.

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

Chemical Engineering M.S.

Areas of Study

Consult the department.

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

Course Requirements

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

All M.S. degree candidates must enroll in the seminar, Chemical Engineering 299, during each quarter in residence. A program of study that encompasses these requirements must be submitted to the departmental Student Affairs Office for approval before the end of the student’s second quarter in residence.

Semiconductor Manufacturing

The requirements for the M.S. degree in the field of semiconductor manufacturing are 10 courses (44 units) and a minimum 3.0 grade-point average overall and in the graduate courses. Students are required to take Chemical Engineering 104C/104CL, C216, 270, 270R, Electrical Engineering 123A, Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical engineering or materials science and engineering electives must be selected, with a minimum of two at the 200 level. A total of at least five graduate (200-level) courses is required. Approved elective courses include Chemical Engineering C214, C218, C219, 223, 234, C240, Electrical Engineering 124, 221B, 223, 224, Materials Science and Engineering 221, 223, 245C.

Courses taken by students who are not enrolled in the semiconductor manufacturing field may not be applied toward the 10-course requirement for the degree. A program of study encompassing the course requirements and/or substitutions must be submitted to the graduate adviser for approval before the end of the first quarter in residence.
**Field Experience.** Students may take Chemical Engineering 270R in the field, working at an industrial semiconductor fabrication facility. This option must meet all course requirements and must be approved by the graduate adviser and the industrial sponsor of the research.

**Comprehensive Examination Plan**

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

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

**Thesis Plan**

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

**Chemical Engineering Ph.D.**

**Major Fields or Subdisciplines**

Consult the department.

**Course Requirements**

All Ph.D. students must take six courses (24 units), including Chemical Engineering 200, 210, and 220. Two additional courses must be taken from those offered by the Chemical and Biomolecular Engineering Department. The third course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. All of these units must be in letter-graded 200-level courses. Students are encouraged to take more courses in their field of specialization. The minor field courses should be selected in consultation with the research adviser and approved by the graduate adviser. A 3.33 grade-point average in graduate courses is required. A program of study to fulfill the course requirements must be submitted for approval to the departmental Student Affairs Office no later than one quarter after successful completion of the preliminary oral examination.

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

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

**Written and Oral Qualifying Examinations**

All Ph.D. students must take a preliminary oral examination that tests their understanding of chemical engineering fundamentals in the areas of thermodynamics, transport phenomena, chemical kinetics, and reactor design. The examination is held at the beginning of Winter Quarter. Students are asked to solve the examination problems in writing and then present them orally to a faculty committee. Students whose first degree is not in chemical engineering may petition to postpone the examination to the following year. Any student failing the Ph.D. preliminary examination may petition to reenter the Ph.D. program after successfully completing the master’s thesis. If the petition is granted, the student may be approved to take the preliminary examination concurrently with the master’s thesis defense.

After successfully completing the required courses and the preliminary oral examination, students must pass the written and oral qualifying examinations. The examinations focus on the dissertation research and are conducted by a doctoral committee consisting of at least four faculty members nominated by the Department of Chemical and Biomolecular Engineering, in accordance with University regulations.

The written qualifying examination consists of a dissertation research proposal that provides a clear description of the problem considered, a literature review of the current state of the art, and a detailed explanation of the approach to be followed to solve the problem. Students first present their ideas for the dissertation research at a precandidacy seminar administered by departmental faculty members of the doctoral committee. The seminar is held during the early part of the Winter Quarter of the second year in residence. Following the seminar, students submit the dissertation research proposal to the doctoral committee. The written examination is due in the seventh week of the Winter Quarter.

The University Oral Qualifying Examination consists of an oral defense of the dissertation research proposal and is administered by the doctoral committee. The oral examination is held within two weeks of submitting the written examination.

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

**Facilities**

**Biomolecular Engineering Laboratories**

The Biomolecular Engineering laboratories are equipped for cutting-edge genetic, molecular, and cellular bioengineering teaching and research. Facilities and equipment include (1) DNA microarray printing and scanning facility, (2) fluorescence microscopy, (3) real-time PCR thermocycler, (4) UV-visible and fluorescence spectrophotometers, (5) HPLC and LC-mass spectrometer, (6) aerobic and anaerobic bioreactors from bench top to 100-liter pilot scale, (7) protein purification facility, (8) potentiostat, galvanostat and impedance analyzer for electroenzymology, (9) membrane extruder and multilayer laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and (10) phosphiomager for biochemical assays involving radiolabeled compounds.

Microbial cells are genetically and metabolically engineered to produce novel compounds that are used as drugs, specialty chemicals, and food additives. Novel gene-metabolic circuits are designed and constructed in microbial cells to perform complex and non-native cellular behavior. These designer cells are cultured in bioreactors, and intracellular states are monitored using DNA microarrays and real-time RT-PCR. Such investigations are coupled with genomic and proteomic efforts, and mathematical modeling, to achieve system-wide understanding of the cell.

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

**Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory**

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

**Electrochemical Engineering and Catalysis Laboratories**

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

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

**Electronic Materials Processing Laboratory**

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

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

**Materials and Plasma Chemistry Laboratory**

The Materials and Plasma Chemistry Laboratory is equipped with state-of-the-art instruments for studying the molecular processes that occur during chemical vapor deposition (CVD) and plasma processing. CVD is a key technology for synthesizing advanced electronic and optical devices, including solid-state lasers, infrared, visible, and ultraviolet detectors and emitters, solar cells, heterojunction bipolar transistors, and high-electron mobility transistors. The laboratory houses a commercial CVD reactor for the synthesis of III-V compound semiconductors. This tool is interfaced to an ultrahigh vacuum system equipped with scanning tunneling microscopy, low-energy electron diffraction; infrared spectroscopy and X-ray photoelectron spectroscopy. This apparatus characterizes the atomic structure of compound semiconductor heterojunction interfaces and determines the kinetics of CVD reactions on these surfaces.

The atmospheric plasma laboratory is equipped with multiple plasma sources and state-of-the-art diagnostic tools. The plasmas generate, at low temperature, beams of atoms and radicals well-suited for surface treatment, cleaning, etching, deposition, and sterilization. Applications are in the biomedical, electronics, and aerospace fields. The laboratory is unique in that it characterizes the reactive species generated in atmospheric plasmas and their chemical interactions with surfaces.

**Nanoparticle Technology and Air Quality Engineering Laboratory**

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

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

Polymer and Separations Research Laboratory

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

Process Systems Engineering Laboratory

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

Faculty Areas of Thesis Guidance

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

James F. Davis, Ph.D. (Northwestern, 1981) Intelligent systems in process, control operations and design, decision support, management of abnormal situations, data interpretation, knowledge databases, pattern recognition.


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

Yufeng Lu, Ph.D. (University of New Mexico, 1996) Semiconductor manufacturing and nanotechnology.


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


Assistant Professors


Lower Division Courses

2. Technology and the Environment. (4) Lecture, four hours; outside study, eight hours. Natural and anthropogenic flows of materials at global and regional scales. Classical 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)

10. Introduction to Chemical and Biomolecular Engineering. (1) Lecture, one hour. General introduction to field of chemical and biomolecular engineering. Description of how chemical and biomolecular engineering analysis and design skills are applied for creative solution of current technological problems in production of microelectronic devices, design of chemical plants for minimum environmental impact, application of nanotechnology to chemical sensing, and genetic-level design of recombinant microbes for chemical synthesis. Letter grading.

Mr. Monbouquette (F)

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

41
Upper Division Courses


101A. Transport Phenomena I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102A, Mathematics 33A, 33B. Corequisite: course 109. Introduction to analysis of fluid flow in chemical, biological, materials, and molecular processes. Fundamentals of momentum transport, Newton law of viscosity, mass and momentum conservation in laminar flow, Navier-Stokes equations, and engineering analysis of flow systems. Letter grading. Mr. Cohen, Mr. Hicks (F)

101B. Transport Phenomena II: Heat Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101B, 102B. Introduction to mass transfer in systems of interest to chemical engineering practice. Fundamentals of mass species transport, Fick law of diffusion, diffusion in chemically reacting flows, interphase mass transfer, multicomponent systems. Letter grading. Mr. Cohen, Mr. Hicks (Sp)


103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101B, 102B. Application of principles of heat, mass, and momentum transport to design and operation of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading. Ms. Chang, Mr. Hicks (Sp)

104A. Chemical Engineering Laboratory I. (6) Lecture, two hours; laboratory, eight hours; outside study, four hours; other, four hours. Requisites: courses 100, 101B, 102B, 104D. Measurements functions. Statistical thermodynamics of ideal gases. Intermolecular interactions and liquid state. Thermodynamics of polymeric materials and biological macromolecules. Letter grading.

104B. Chemical and Biomolecular Engineering Laboratory II. (6) Lecture, two hours; laboratory, eight hours; outside study, four hours; other, four hours. Requisites: courses 101C, 103, 104A. Course consists of four experiments in chemical engineering unit operations, each of two weeks duration. Students present their results both written and orally. Writing, critical thinking, and oral presentation. Experimental techniques, scaleup and process design, and error analysis. Letter grading. Mr. Senkan (FW)

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, six hours. Requisites: courses 101C, 104A, Electrical Engineering 2, Materials Science 120. Corequisite: course 104C. Introduction to processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, and statistical design of experiments and error analysis. Presentation of student results in both written and oral form. Letter grading. Ms. Chang, Mr. Hicks (Sp)

104CL. Semiconductor Processing Laboratory. (3) Lecture, four hours. Requisites: courses 101G, 104A, Electrical Engineering 2, Materials Science 120. Corequisite: course 104C. Principles and engineering examples used throughout to illustrate application of molecular beam epitaxy, metalorganic chemical vapor deposition, plasma etching, and metalization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Ms. Chang, Mr. Hicks (Sp)


104DL. Molecular Biotechnology Laboratory: From Gene to Product. (4) Laboratory, eight hours. Requisites: courses 101C, 103, 104A. Corequisite: course 104D. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid, transformation of construct into E. coli, production of gene product in bioreactor, downstream processing of bioreactor broth to purified recombinant protein, and characterization of purified protein. Letter grading. Mr. Liao (W)

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

107. Process Dynamics and Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101C, 103, 106. Principles of dynamics modeling and start-up behavior of chemical engineering processes. Chemical process control elements. Design and applications of chemical process control computer letter grading. Mr. Christofides, Mr. Manoussiotakis (W)

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

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 106, 108A, and either Civil Engineering 15 or Mechanical and Aerospace Engineering 20. Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as computer-aided tools. Letter grading. Mr. Christofides (F)


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


113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Requisites: courses 101C, 102B. Integrated approach to air pollution, including concentrations of atmospheric pollutants, air pollution standards, air pollution sources and control technology, and relationships of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading. Mr. Friedlander (F)
C114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal and semiconduc
tor surface finishing, passivity, electrodeposition, electron deposition, polymers, and fuel cells, electrosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C214. Letter grading. Mr. Nobe (F) C115. Biochemical Reaction Engineering. (4) Lect
ture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101C and 106, or Chemistry 156. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biophysical reactors. May be concurrently scheduled with course CM215. Letter grading. Mr. Liao, Mr. Monbouquette (Sp) C116. Surface and Interface Engineering. (4) Lec
ture, four hours; discussion, one hour; outside study, eight hours. Requisite: Chemistry 113A. Introduction to surface and interface engineering; materials particularly catalytic surface and thin films for solid-
state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of their surfaces and inter
faces. Examination of engineering applications, in-
cluding catalytic surfaces, interfaces in microelectron-
cics, and solid-state laser. May be concurrently sched-
uled with course C216. Letter grading. Mr. Chang, Mr. Hicks (F) C118. Multimedia Environmental Assessment. (4) Lecture, four hours; preparation, two hours; out-
side study, six hours. Requisites: courses 101C, 102B, or course 102A and course 106. Examination of source remedi-
ations, waste minimization, transport and fate of chemi-
ical pollutants in environment, intermedia transfers of pollutants, multimedia modeling of chemical partition-
ing in environment, exposure assessment and funda-
es. (4) Lecture, four hours; discussion, one hour; out-
side study, seven hours. Requisite: course 108A. Systematic methods for design of environment-
friendly processes. Development of the methods at mole-
cular, unit-operations, and network levels. Syn-
thesis of mass exchange, heat exchange, and reac-
tor networks. Concurrently scheduled with course C219. Letter grading. Mr. Manousiosthakis (Sp) C121. Membrane Science Technology. (4) Lec-
ture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, with emphasis on separations at macro, nano, and molecular/angstrom scale with membranes. Relationship
between structure/morphology of dense and porous membranes and their separation characteristics. Use of membranes in design of select separa-
tion devices and models of membrane transport (flux and selectivity). Examples provided from various fields/ applications, including biotechnology, microelectron-
ics, chemical processes, sensors, and biodiagnostics. Con-
currently scheduled with course C221. Letter grading. Mr. Cohen (W) C125. Bioseparations and Bioprocess Engineer-
ing. (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 isolat-
ing 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) C123. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 107. Introduction to advanced process control topics include (1) Lyapunov stability for autonomous nonlinear systems including converse theorems, (2) input to state stabil-
ity, interconnected systems, and small gain theore-
ems, (3) model robust controllers for various classes of nonlinear systems, (4) model predictive control and linear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed param-
ture, four hours; outside study, eight hours. Requi-
ses: course 101A, or course 102B, or course 106. Use of recently developed techniques for predicting flow and deposition, optical properties, experimental
methods, dynamics and control of particle for-
mation processes. Concurrently scheduled with course C240. Letter grading. Mr. Friedlander (F or W) CM145. Molecular Biotechnology Engineering. (4) Same as Biomedical Engineering CM145.) Lec-
ture, four hours; discussion, one hour; outside study, eight hours. Selected topics in molecular biology that form the basis of biotechnology and biomedicin
industry today. Topics include recombinant DNA tech-
nology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein
deriving, DNA-based diagnostics and DNA mi-
ocroarrays, antibody and protein-based diagnostics,
genomics and bioinformatics, isolation of human
genes, gene therapy, and tissue engineering. Con-
currently scheduled with course CM245. Letter grading. Mr. Liao (F) C188. Special Courses in Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in chemical engineering for undergrad-
uate students. Selection of specific topics in tem-
porary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. 194. Research Group Seminars: Chemical Engi-
neering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research meth-
ods and current literature in field. Letter grading. 199. Advanced Research in Energy Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/sen-
niors. Supervised individual research or investigation of selected topic under guidance of faculty mentor. Culminating paper or project required. May be re-
petition for credit with school approval. Individual con-
tact required; enrollment petitions available in Office
of Academic and Student Affairs. Letter grading. 200. Advanced Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requi-
ses: course 102B. Phenomenological and statisti-
cal thermodynamics of chemical and physical sys-
tems with engineering applications. Presentation of
role of atomic and molecular spectra and intermolec-
ular forces in interpretation of thermodynamic proper-
ties of gases, liquids, solids, and plasmas. Letter grading. Mr. Nobe (F) 201. Methods of Molecular Simulation. (4) Lec-
ture, four hours; outside study, eight hours. Requisite: course 230 or Chemistry 210, or Physics 215A. Modern simulation techniques for classical molecular systems. Monte Carlo and molecular dynamics in various
systems. Applications to liquids, solids, and polymers. Letter grading. Mr. Cohen (W) 210. Advanced Chemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101C, 106. Principles of chemi-
cal reactor analysis and design. Particular emphasis
on simultaneous effects of chemical reaction and mass transfer on noncatalytic and catalytic reactions in fixed and fluidized beds. Letter grading. Mr. Senkan (W) C211. Cryogenics and Low-Temperature Process-
es. (4) Lecture, four hours; discussion, one hour; out-
side study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryogenics engineering science pertaining to industrial low-temperature processes. Basic ap-
proaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-tem-
perature behavior of matter, optimization of cryosys-
tems and other special conditions. Concurrently sched-
uled with course C111. Letter grading. (F) C212. Polymer Processes. (4) Lecture, four hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting a reaction scheme, polymerization techniques, polymer characteriza-
tion. Mechanic properties. Rheology of macromole-
cules, polymer process engineering. Diffusion in polymer systems. Polymer in biomedical appli-
cations and in microelectronics. Concurrently sched-
uled with course C112. Letter grading. Mr. Cohen (Sp) C213. Polymers in Bioengineering. (4) Lecture, four hours; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electro-
chemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to anal-
ysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semi-
conductors, electrochemical metal and semiconduc-
tor surface finishing, passivity, electrodeposition, elec-
trosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. Mr. Cohen (Sp) C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electro-
chemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to anal-
ysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semi-
conductors, electrochemical metal and semiconduc-
tor surface finishing, passivity, electrodeposition, elec-
trosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. Mr. Cohen (Sp) C221. Cryogenic and Cryogenics Engineering. (4) Same as Biomedical Engineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101C, 102B (or Materials Science 130). Fundamentals of electro-
chemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to anal-
ysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semi-
conductors, electrochemical metal and semiconduc-
tor surface finishing, passivity, electrodeposition, elec-
trosynthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. Mr. Cohen (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, and turbulent transport. Letter grading. Mr. Cohen, Mr. Friedlander (F)

C221. Membrane Science Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, 101C, 103. Fundamentals of science and technology, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and performance and selectivity. Use of nanotechnology for design of selective membranes and models of membrane transport (flux and selectivity). Examples provided from various fields/applications. Letter grading. Mr. Cohen, Mr. Friedlander (F)


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

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-cycles; inventories; life-cycle impact assessment; design for energy efficiency; design for waste minimization, computer-aided design tools, materials selection methods. Letter grading. Mr. Manousiouthakis (W)

CM225. Bioseparations and Bioprocess Engineering. (4) (Same as Biomedical Engineering M225.) Lecture, four hours; outside study, eight hours. Requisites: courses 101C and 103, or Chemistry 156. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food, pharmaceuticals, and protein products of biological reactors. Concurrently scheduled with course C125. Letter grading. Mr. Liu, Mr. Monbouquette (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 cold atom beams. Molecular-beam studies of gas-surface interactions, including energy accommodations and heterogeneous reactions. Application to air pollution control and to catalysis. Letter grading.

232. Combustion Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 106, 200, or Mechanical and Aerospace Engineering 132. Fundamentals of combusting, reactive, and turbulent flows. Letter grading. Ms. Chang, Mr. Hicks (Sp)

C235. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced prerequisite: course 233A. Introduction to advanced process control. Topics include (1) Lyapunov stability for autonomous nonlinear systems including converse theorems, (2) input to state stability, positive realness, and scattering, (3) small gain theorems, (4) model constructive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course C135. Letter grading. Mr. Christofides (Sp)

236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 210, 212E. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic devices. Topics include reactor design, transport phenomena, nucleation, condensation, growth, and deposition of deposited films, and relationship between process conditions and film properties. Letter grading. Mr. Hicks (Sp)

C240. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Technology of particle/gas systems. Stochastic control, systems with multiplicative noise. Applications to air pollution control and to catalysis. Letter grading. Mr. Cohen, Mr. Hicks (Sp)

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


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


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

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

M280A. Linear Dynamic Systems. (4) (Same as Electrical Engineering M240A and Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvectors and eigenvalues, singular values, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Comparisons with transfer function techniques. Letter grading.

M280C. Optimal Control. (4) (Same as Electrical Engineering M240C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisites: course CM245 or Mechanical and Aerospace 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. Requisites: courses M280A, M282A. Designed for graduate students. Introduction to advanced control and analysis of systems description methods for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Banach and Hilbert spaces, semigroup theory, convergence theory in function spaces); (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition); (3) nonlinear and robust control of nonlinear hyperbolic and parabolic partial differential equations (PDEs); (4) applications to reaction-process processes. Letter grading. Mr. Christofides


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

297. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Electrical Engineering M246S and Mechanical and Aerospace Engineering M299A.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

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

299. Departmental Seminar. (2) Seminar, two hours. Limited to graduate chemical engineering students. Seminar 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.

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

495A. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, four hours; one-day intensive training at beginning of Fall Quarter. Limited to graduate chemical engineering students. Required of all new teaching assistants. Special seminar on communicating chemical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of grading, advising, and rapport with students. S/U grading.

495B. Teaching with Technology for Teaching Assistants. (2) Seminar, two hours; outside study, four hours. Limited to graduate chemical engineering students. Designed for teaching assistants interested in learning more about effective use of technology and ways to incorporate that technology into their classrooms for benefit of student learning. S/U grading.

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

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate chemical engineering students. Petition forms to request enrollment may be obtained from assistant dean. Graduate Studies. Supervised investigation of advanced technical problems. 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. S/U grading.


Civil and Environmental Engineering

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

Adjunct Associate Professors
Patrick J. Fox, Ph.D.
Issam Najm, 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, hydrology and water
resources engineering, and environmental engineering.

The ABET-accredited civil engineering curriculum leads to a B.S. in Civil Engineering, a broad-based education in structural engineering, geotechnical engineering, hydrology and water resources engineering, and environmental engineering. This program is an excellent foundation for entry into professional practice in civil engineering or for more advanced study.

At the graduate level, M.S. and Ph.D. degree programs are offered in the areas of structures (including structural/earthquake engineering and structural mechanics), geotechnical engineering, hydrology and water resources engineering, and environmental engineering. In these areas, research is being done on a variety of problems ranging from basic physics and mechanics problems to critical problems in earthquake engineering and in the development of new technologies for pollution control and water distribution and treatment.

Department Mission

The Civil and Environmental Engineering Department seeks to exploit its subfield teaching and research strengths as well as to engage in multidisciplinary collaboration. This occurs within the context of a central guiding theme: engineering sustainable infrastructure for the future. Under this theme the department is educating future engineering leaders, most of whom will work in multidisciplinary environments and confront a host of twenty-first-century challenges. With an infrastructure-based vision motivating its teaching and research enterprise, the department conceptualizes and orients its activity toward broadening and deepening fundamental knowledge of the interrelationships among the built environment, natural systems, and human agency.

Undergraduate Program Objectives

The objectives of the ABET-accredited civil engineering curriculum at UCLA are to (1) provide graduates with a solid foundation in basic mathematics, science, and humanities, as well as fundamental knowledge of relevant engineering principles, (2) provide students with the capability for critical thinking, engineering reasoning, problem solving, experimentation, and teamwork, (3) prepare graduates for advanced study and/or professional employment within a wide array of industries or governmental agencies, (4) produce graduates who understand ethical issues associated with their profession and who are able to apply their acquired knowledge and skills to the betterment of society, and (5) foster in students a respect for the educational process that is manifest by a lifelong pursuit of learning.

Undergraduate Study

Civil Engineering B.S.

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 1, 15; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1), 4AL.

The Major

Required: Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A, Civil and Environmental Engineering 101, 103, 108, 110, 120, 135A, 151, 153, Materials Science and Engineering 104, Mechanical and Aerospace Engineering 103, 182A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and at least nine major field elective courses (36 units) that must include the required courses in two of the following tracks:

Environmental Engineering: One laboratory course from Civil and Environmental Engineering 156A or 156B or M166L and one major project design course from 157B or 157C; recommended: courses 154, 155, 163, 164, M166

Geotechnical Engineering: Civil and Environmental Engineering 121 and 128L; recommended: courses 123, 125, 135B, 137, 142

Structural Engineering and Mechanics: Civil and Environmental Engineering 135B, one lecture course from 130, 135C, 137, 141, or 142, one laboratory course from 130L, 135L, 137L, or 142L (must select 130L or 137L or 142L if 135L is selected from structures major project design list), and one structures major project design course from 135L or 144 or 147 (must select 144 or 147 if 135L is selected from laboratory list); recommended: courses 121, 125, 130, 130L, 135L, 137, 137L, 141, 142, 142L, 143, 144, 147

Water Resources Engineering: Civil and Environmental Engineering 150 and 157L; recommended: courses 154, 156A

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.
Graduate Study
For information on graduate admission, see Graduate Programs, page 24.
The following introductory information is based on the 2006-07 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the “Publications” link at http://www.gdn.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 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199. The M.S. degree offers four fields of specialization that have specific course requirements.

Environmental Engineering
Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 150 or 151, 153; Mathematics 32A, 32B, 33A; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.
Required Graduate Courses. Civil and Environmental Engineering 254A, 255A, 255B.
Elective Courses. Civil and Environmental Engineering 110, 154, 155, 157B, 157C, 163, 164, M166, 253, 258A, 261B, 263A, 263B, 265A, 265B, 266; a maximum of two of the following courses for students electing the thesis plan or a maximum of three of the following courses for students electing the comprehensive examination plan: Environmental Engineering 150, 250B, 250C, 250D, 252, 253, 260, 265A, 265B.

Geotechnical Engineering
Required Preparatory Courses. Civil and Environmental Engineering 108, 120, 121.
Required Graduate Courses. Civil and Environmental Engineering 220, 221, 223, 224.
Major Field Elective Courses. Minimum of three courses must be selected from Civil and Environmental Engineering 123, 125, 128L, 222, 225, 226, 227, 228L.

Hydrology and Water Resources Engineering
Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 150 or 151, 153; Mathematics 32A, 32B, 33A; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.
Required Graduate Courses. Minimum of five courses must be selected from Civil and Environmental Engineering 250A, 250B, 250C, 250D, 252, 253, 260, 265A, 265B.
Elective Courses. Civil and Environmental Engineering 150, 164, 254A, 255A, 255B, 263A; a maximum of two of the following courses for students electing the thesis plan or a maximum of three of the following courses for students electing the comprehensive examination plan: Atmospheric and Oceanic Sciences M203A, 218, Computer Science 270A, 271A, 271B, Electrical Engineering 236A, 236B, 236C, M237, Mathematics 269A, 269B, 269C. Students may petition the department for permission to pursue programs of study that differ from the above norms.

Structural/Earthquake Engineering
Required Preparatory Courses. Civil and Environmental Engineering 135A, 135B, 141, 142.
Required Graduate Courses. Civil and Environmental Engineering 235A, 246; at least three of the following courses: Civil and Environmental Engineering 241, 242, 243A, 243B, 244, 247, 248.

Structural Mechanics
Required Preparatory Courses. Civil and Environmental Engineering 130, 135A, 135B.
Required Graduate Courses. Civil and Environmental Engineering 232, 235A, 235B, 236, M237A.
Elective Courses. Undergraduate: No more than two courses from Civil and Environmental Engineering 135C, 137, 137L; graduate: Civil and Environmental Engi-

**Comprehensive Examination Plan**

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

**Thesis Plan**

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

**Civil Engineering Ph.D.**

**Major Fields or Subdisciplines**

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

**Course Requirements**

There is no formal course requirement for the Ph.D. degree, and students may theoretically substitute coursework by examinations. However, students normally take courses to acquire the knowledge needed for the required written and oral preliminary examinations. The basic program of study for the Ph.D. degree is built around one major field and two minor fields. The major field has a scope corresponding to a body of knowledge contained in a detailed Ph.D. field syllabus available on request from the department office. Each minor field normally embraces a body of knowledge equivalent to three courses from the selected field, at least two of which are graduate courses. Grades of B— or better with a grade-point average of at least 3.33 in all courses included in the minor field, are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor fields are chosen to support the major field and are usually subsets of other major fields.

**Written and Oral Qualifying Examinations**

After mastering the body of knowledge defined in the major field, students take a written preliminary examination. When the examination is passed and all coursework is completed, students take an oral preliminary examination that encompasses the major and minor fields. Both preliminary examinations should be completed within the first two years of full-time enrollment in the Ph.D. program. Students may not take an examination more than twice.

After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

*Note: Doctoral Committees.* A doctoral committee consists of a minimum of four members. Three members, including the chair, must be “inside” members who hold full-time faculty appointments at UCLA in the student’s major department in HSSEAS. The “outside” member must be a UCLA faculty member outside the student's major department.

**Fields of Study**

**Environmental Engineering**

Research in environmental engineering focuses on the understanding and management of physical, chemical, and biological processes in the environment and in engineering systems. Areas of research include process development for water and wastewater treatment systems and the investigation of the fate and transport of contaminants in the environment.

**Geotechnical Engineering**

Research in geotechnical engineering focuses on understanding and advancing the state of knowledge on the effects that soils and soil deposits have on the performance, stability, and safety of civil engineering structures. Areas of research include laboratory investigations of soil behavior under static and dynamic loads, constitutive modeling of soil behavior, behavior of structural foundations under static and dynamic loads, soil improvement techniques, response of soil deposits and earth structures to earthquake loads, and the investigation of geotechnical aspects of environmental engineering.

**Hydrology and Water Resources Engineering**

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

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

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

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

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

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

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

Experimental Fracture Mechanics Laboratory
The Experimental Fracture Mechanics Laboratory is used for preparing and testing specimens using modern dynamic testing machines to develop an understanding of fracture mechanics and to become familiar with experimental techniques available to study crack tip stress fields, strain energy release rate, surface flaws, and crack growth in laboratory samples.

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

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

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

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

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

Research Laboratories
Building Earthquake Instrumentation Network
The Building Earthquake Instrumentation Network consists of more than 100 earthquake strong motion instruments in three campus buildings to measure the response of actual buildings during earthquakes. When combined with over 50 instruments placed in four Century City high-rises and retail buildings, this network, which is maintained by the U.S. Geological Society and State of California Division of Mines and Geology Strong Motion Program, represents the most detailed building instrumentation network in the world. The goal of the research conducted using the response of these buildings is to improve computer modeling methods and the ability of structural engineers to predict the performance of buildings during earthquakes.

Environmental Engineering Laboratories
The Environmental Engineering Laboratories are used for conducting water and wastewater analysis, including instrumental techniques such as GC, GC/MS, HPLC, TOC, IC, and particle counting instru-

ments. A wide range of wet chemical analysis can be made in this facility with 6,000 square feet of laboratory space and an accompanying 4,000-square-foot rooftop facility where large pilot scale experiments can be conducted. Additionally, electron microscopy is available in another laboratory.

Recently studies have been conducted on oxygen transfer, storm water toxicity, transport of pollutants in soil, membrane fouling, removal from drinking water, and computer simulation of a variety of environmental processes.

Experimental Mechanics Laboratory
The Experimental Mechanics Laboratory supports two major activities: the Optical Metrology Laboratory and the Experimental Fracture Mechanics Laboratory.

In the Optical Metrology Laboratory, tools of modern optics are applied to engineering problems. Such techniques as holography, speckle-interferometry, Moiré analysis, and fluorescence-photo mechanics are used for obtaining displacement, stress, strain, or velocity fields in either solids or liquids. Recently, real-time video digital processors have been combined with these modern optical technical techniques, allowing direct interfacing with computer-based systems such as computer-aided testing or robotic manufacturing.

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

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

Associated with the laboratory is an electrohydraulic universal testing machine with force capacity of 100 tons. The machine is used mainly to apply tensile and compressive loads to specimens so that the properties of the materials from which the
specimens are made can be determined. It can also be used in fatigue-testing of small components.

**Soil Mechanics Laboratory**
The Soil Mechanics Laboratory is used for standard experiments and advanced research in geotechnical engineering, with equipment for static and dynamic triaxial and simple shear testing. Modern computer-controlled servo-hydraulic closed-loop system supports triaxial and simple shear devices. The system is connected to state-of-the-art data acquisition equipment. The laboratory also includes special simple shear apparatuses for small-strain static and cyclic testing and for one-dimensional or two-dimensional cyclic loading across a wide range of frequencies. A humidity room is available for storing soil samples.

**Faculty Areas of Thesis Guidance**

**Professors**

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

Jiann-Wen Ju, Ph.D. (UC Berkeley, 1988)  
Earthquake engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties

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

**Adjunct Professors**

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

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

Patrick J. Fox, Ph.D. (Wisconsin, Madison, 1992)  
Flow and transport in unsaturated soils, settlement analysis, soil properties and testing, environmental geotechnology, reinforced soil walls, discrete element modeling, and smooth particle hydrodynamics

Issam Najm, Ph.D. (Illinois, Urbana-Champaign, 1990)  
Water chemistry; physical and chemical processes in drinking water treatment

**Assistant Professors**

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

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

**Associate Professor**

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

**Senior Lecturer**

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

**Soil Mechanics Laboratory**
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Patrick J. Fox, Ph.D. (Wisconsin, Madison, 1992)  
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Issam Najm, Ph.D. (Illinois, Urbana-Champaign, 1990)  
Water chemistry; physical and chemical processes in drinking water treatment

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

**Assistant Professors**

Scott J. Brandenburg, Ph.D. (UC Davis, 2005)  
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Issam Najm, Ph.D. (Illinois, Urbana-Champaign, 1990)  
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Daniel E. Pradel, Ph.D. (U. Tokyo, 1987)  
Soil mechanics and foundation engineering

**Adjunct Associate Professors**

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

**Lower Division Courses**

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

2. **Geotechnical Engineering.** (2 Lecture, two hours; laboratory, two hours; outside study, two hours. Introduction to computer programming using MATLAB. Selected topics in programming, with emphasis on numerical techniques and methodology as applied to civil engineering programs. Letter grading. Mr. Chen, Mr. Ju (F,WW,Sp)

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

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

4. **Professional Practice Issues in Structural Engineering.** (2 Seminar, two hours; outside study, four hours. Introduction to issues of professional practice in structural engineering. Content and methodology as applied to civil engineering programs. Letter grading. Mr. Yeh (F)

5. **Environmental Science and Engineering.** (4 Lecture, three hours; laboratory, two hours. Introduction to environmental science and engineering. P/NP grading. Mr. Yeh (F)

6. **Geotechnical Engineering.** (2 Lecture, two hours; laboratory, two hours; outside study, two hours. Introduction to computer programming using MATLAB. Selected topics in programming, with emphasis on numerical techniques and methodology as applied to civil engineering programs. Letter grading. Mr. Chen, Mr. Ju (F,WW,Sp)

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

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9. **Professional Practice Issues in Structural Engineering.** (2 Seminar, two hours; outside study, four hours. Introduction to issues of professional practice in structural engineering. Content and methodology as applied to civil engineering programs. Letter grading. Mr. Yeh (F)

10. **Environmental Science and Engineering.** (4 Lecture, three hours; laboratory, two hours. Introduction to environmental science and engineering. P/NP grading. Mr. Yeh (F)
121. Design of Foundations and Earth Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 120. Design methods for foundations and earth structures. Site investigation, including evaluation of soil properties for design. Design of footings and piles, including stability and settlement calculations. Design of slopes and earth retaining structures. Letter grading.

Mr. Stolzenbach (W)

123. Advanced Geotechnical Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 121. Analysis and design of earth dams, including response and Fourier spectra. Ground motion hazard analysis, including fault characteristics, attenuation relationships, and site effects. Normal and sliding forces. Time-histories, load selection. Letter grading.

Mr. Stewart (W)


Mr. Ju (F)


Mr. Ju (F)


Mr. Taciroglu (W)


Mr. Taciroglu (W)

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

Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; matrix displacement method; analysis concepts based on analysis of indeterminate structures using force method; introduction to displacement method and energy concepts. Letter grading.

Mr. Ju (W)

135C. Finite Element Methods. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 130, 135B. Direct approximate function for eigenvalues and eigenvectors, solution of partial differential equations, parametric 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)

137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics course for civil engineering students. Elastic, free, forced vibration, and earthquake response spectra analysis for single and multidegree of freedom systems. Bistatic, impact, and torsional vibrations of beams. Letter grading.

Mr. Ju (F)

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

Mr. Wallace (F)


Mr. Wallace (W)

142L. Reinforced Concrete Structural Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study. Requisites: courses 135B, 142. Limited enrollment. Design considerations used for reinforced concrete beams, columns, slabs, and joints evaluated using analysis and experiments. Links between theory, building codes, and experimental results. Students demonstrate accuracies and limitations of calculation procedures used in design of reinforced concrete. Fundamental concrete properties and materials, design skills for written and oral presentations. Letter grading.

Mr. Wallace (Sp)


Mr. Wallace (Sp)

Mr. Wallace (Sp)


Mr. Wallace (W)

150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Mechanical and Aerospace Engineering 103. Recommended: course 15. Study of hydrologic cycle and relevant atmospheric processes, water and energy balance, radiation, precipitation formation, evaporation, transpiration, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading.

Mr. Margulis (F)

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Mechanical and Aerospace Engineering 103. Principles of hydraulics, flow of water in open channels and pressure conduits, regulatory dam systems, hydraulic machinery, hydroelectric power. Introduction to system analysis and design applied to water resources engineering. Letter grading.

Ms. Hogue (W)


Ms. Stolzenbach (F)

154. Chemical Fate and Transport in Aquatic Environments. (4) Lecture, four hours; outside study, eight hours. Requisites: Chemistry 20A, 20B, Mathematics 31A, 31B, Physics 1A, 1B. Fundamental physical, chemical principles governing water movement and fate of chemicals in surface waters and groundwater. Topics include physical transport in various aquatic environments, air-water exchange, chemical and physical reaction processes, chemical sorption, biodegradation, and bioaccumulation. Practical quantitative problems solved considering both reaction and transport of chemicals in environments. Letter grading.

Ms. Jay (F)

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

Mr. Stolzenbach (F)

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

Mr. Stolzenbach (F)

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Laboratory, six hours; discussion, two hours; outside study, four hours. Requisites: Chemistry 20A, 20B. Characterization and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and other constituents, which are used in unit operation experiments that include reactor dynamics, aeration, gas stripping, coagulation/flocculation, and membrane separation. Letter grading.

Mr. Stenstrom (W)

157B. Design of Water Treatment Plants. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; other, four hours. Requisite: course 155. Water quality standards and regulations, overview of water treatment plants, design of unit operations, pre-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)

157L. Hydrologic Analysis and Design. (4) Lecture, one hour; laboratory, four hours; other, four hours. Requisites: courses 150, 151. Collection, computation, and interpretation of data for quantification of surface water components of hydrologic cycle, including precipitation, evaporation, infiltration, surface flow, groundwater flow, and evapotranspiration. Design parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Field trip required. Letter grading.

Mr. Hogue (Sp)

157M. Hydrology of Mountain Watersheds. (2) Fieldwork, three hours; laboratory, two hours; outside study, one hour; one field trip. Requisite: course 150 or 157L. Advanced field-based course with focus on study of catchment processes in snow-dominated and mountainous regions. Students measure and quantify snowpack properties and watershed fluxes, investigate geographic properties of surface and groundwater systems, and classify mountain streams and flooding potential. Letter grading.

Ms. Hogue (Sp)

163. Introduction to Atmospheric Chemistry and Air Pollution Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 153, Chemistry 20A, 20B, Mathematics 31A, 31B, Physics 1A, 1B. Description of processes affecting chemical composition of troposphere: air pollutants and standards, urban and rural ozone, aerosol pollution, formation/deposition of acid precipitation. Letter grading.

Ms. Jay (W)


Ms. Jay (W)

M166L. Environmental Microbiology and Biotechnology Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, two hours. Corequisite: course M166. General laboratory practice within environmental microbiology, sampling of environmental samples, classical and modern molecular techniques for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples, laboratory setups for studying environmental biotechnology. Letter grading.

Ms. Jay (Sp)

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

Mr. Stewart (Sp)

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

FWSp

194. Research Group Seminars: Civil and Environmental Engineering. (2 to 8) Seminar, for students with faculty permission or of research of faculty members or students. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with topic or instructor change. Letter grading.

FWSp

199. Directed Research in Civil and Environmental Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with topic or instructor change. Letter grading.

FWSp

Graduate Courses


Mr. Stewart (F)


Mr. Brandenberg (W)
222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Review of engineering problems involving soil dynamics. Fundamentals of theoretical soil dynamics: response of sliding block-on-a-plane to cyclic earthquake loads, application of theories of single degree-of-freedom (DOF) system, multiple DOF system and one-dimensional wave propagation. Fundamentals of cyclic soil behavior: stress-strain-pore water pressure behavior, shear moduli and damping, cyclic settlement and concept of volumetric cyclic threshold shear strain. Introduction to modeling of cyclic soil behavior. Letter grading. Mr. Vucetic (W)

223. Earth Retaining Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 120, 121. Basic concepts of theory of earth pressures. Analysis of retaining quasiconcave grouted далее...

Mr. Ju (W)


249. Selected Topics in Structural Engineering and Mechanics. (2) Lecture, two hours; outside study, six hours. Review of recent research and developments in structural engineering and mechanics. Structural analysis, finite elements, structural stability, dynamics of structures, structural design, earthquake engineering, ground motion, elasticity, plasticity, structural mechanics, mechanics of composites, and constitutive modeling. May be repeated for credit. S/U grading. Mr. Ju (Sp)


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

250D. Water Resources Systems Engineering. (4) Formerly numbered 251.) Lecture, four hours; outside study, eight hours. Requisite: course 151. Application of mathematical programming techniques to water resources systems. Topics include reservoir management and operation; optimal timing, sequencing and sizing of water resources projects; and multiobjective planning and conjunctive use of surface water and groundwater. Emphasis on management of water quantity. Letter grading. Mr. Yeh (Sp)

251A. Rainfall-Runoff Modeling. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 251C. Introduction to hydrologic modeling concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis, and application of models for flood forecasting and prediction of streamflows in water resource applications. Letter grading. Ms. Hogue (Sp)

251C. Mathematical Modeling of Contaminant Transport in Groundwater (4) Formerly numbered 250C.) Lecture, four hours; laboratory, eight hours. Requisites: courses 250B, 253. Phenomena and mechanisms of hydrodynamic dispersion, governing equations of mass transport in porous media, various analytical, numerical, and probabilistic solution determination of dispersion parameters by laboratory and field experiments, coupled and multiphase pollution problems, computer programs and applications. Letter grading. Mr. Yeh (W)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; outside study, eight hours. Requisites: course 109A, one or more courses from Economics 1, 2, 11, 100, 101. Economic theory and applications in analysis and management of water and environmental problems; application of price theory to water resources management and regional resources; benefit-cost analysis with applications to water resources and environmental planning. Letter grading. Mr. Yeh (Sp)


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

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

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

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

259A. Selected Topics in Environmental Engineering. (2) Lecture, two hours; outside study, four hours. Review of recent research and developments in environmental engineering. Water and wastewater treatment systems, nonpoint pollution, multimedia impacts. May be repeated for credit. S/U grading. Mr. Stoltenbach (F, Sp)

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

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

261. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 254A, 255A. Colloidal interactions, colloidal stability, colloidal hydrodynamics, surface chemistry, adsorption of pollutants on colloidal surfaces, transport of colloids in porous media, coagulation, and particle deposition. Consideration of applications to colloidal processes in aquatic environments. Letter grading. Mr. Stenstrom (Sp)

261B. Advanced Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255B. In-depth treatment of selected topics related to biological treatment of waters and wastewaters, such as biodegradation of xenobiotics, pharmaceuticals, emerging pollutants, toxicity, and nutrients. Discussion of theoretical aspects, experimental observations, and recent literature. Application to important and emerging environmental problems. Letter grading. Mr. Stenstrom (Sp)

M262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M202A.) Lecture, three hours. Requisite for undergraduate graduates: Chemistry 20B. Principles of chemical kinetics, thermodynamics, spectroscopy, and photochemistry; chemical composition and history of Earth’s atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and climate. S/U or letter grading. Mr. Stenstrom (W)

M262B. Atmospheric Diffusion and Air Pollution. (4) (Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complexes; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U (for majors with consent of instructor after successful completion of written and oral comprehensive examination and for nonmajors at discretion of major department) or letter grading.
263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Transport processes in surface water, groundwater, and atmosphere. Emphasis on exchanges across phase boundaries: sediment/water interface; air/water gas exchange; particles, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading. Mr. Stolzenbach (W)

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

265A. Mass Transfer in Environmental Systems. (4) Lecture, four hours; computer applications, two hours; outside study, eight hours. Designed for graduate environmental engineering program students. Physical chemistry and mass transfer fundamentals related to contaminant fate and transport in soil, air, and water systems, including soil/water sorption and desorption, contaminant retardation, vaporization and dissolution of nonaqueous phase liquids (NAPL), and other environmental systems. Letter grading. Mr. Stolzenbach (F)

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

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

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

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

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

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

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

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

The undergraduate and graduate studies and research projects in computer science are supported by significant computing resources. In addition to the departmental computing facility, there are over a dozen laboratories specializing in areas such as distributed systems, multimedia computer communications, distributed sensor networks, VLSI systems, VLSI CAD, embedded and reconfigurable systems, computer graphics, and artificial intelligence. Also, the Cognitive Systems Laboratory is engaged in studying computer systems that emulate or support human reasoning. The Biocybernetics Laboratory is devoted to multidisciplinary research involving the application of engineering and computer science methods to problems in biology and medicine.

The B.S. degree may be attained either through the Computer Science and Engineering major or through the Computer Science major described below.

In addition to the B.S. in Computer Science and Engineering and the B.S. in Computer Science, HSSEAS offers M.S. and Ph.D. degrees in Computer Science, as well as minor fields for graduate students seeking engineering degrees. In cooperation with the John E. Anderson Graduate School of Management, the Computer Science Department offers a concurrent degree program that enables students to obtain the M.S. in Computer Science and the M.B.A. (Master of Business Administration).

Department Mission

The Computer Science Department strives for excellence in creating, applying, and imparting knowledge in computer science and engineering through comprehensive educational programs, research in collaboration with industry and government, dissemination through scholarly publications, and service to professional societies, the community, state, and nation.

Computer Science and Engineering Undergraduate Program Objectives

The educational goal of the computer science and engineering program is to produce graduates who are well grounded in core computer science knowledge, but who also have an understanding of electrical and electronic circuits. They should have the problem-solving and other professional skills that will enable them to achieve their full potential and to excel in their chosen career paths.

The overall objective of the program is to graduate students who are (1) prepared for entry-level positions as practicing computer scientists or computer engineers or for continued education in graduate programs through core scientific and engineering knowledge, laboratory and design experience, a solid grounding in the principal areas of computer science and engineering, and exposure to the current state of the art, (2) positioned for sustained career achievement through cultivation of critical professional skills, including teamwork, written and oral communications, problem-solving abilities, a commitment to lifelong learning, core ethical values, and an understanding of the implications of one’s work on society, and (3) prepared for practice in computer systems engineering at the interface of digital hardware and software and the electronic circuits that interface computers to the analog world.

Students will be prepared to contribute in the fertile application areas where computing and other technical fields intersect through substantial knowledge of at least one additional engineering discipline or technical application area.

Computer Science Undergraduate Program Objectives

The educational goal of the computer science program is to produce graduates who are well grounded in core computer science knowledge and have the problem-solving and other professional skills that will enable them to achieve their full potential and to excel in their chosen career paths.
The overall objective of the program is to graduate students who are (1) prepared for entry-level positions as practicing computer scientists or for continued education in graduate programs through core scientific and engineering knowledge, laboratory and design experience, a solid grounding in the principal areas of computer science, and exposure to the current state of the art, (2) positioned for sustained career achievement through cultivation of critical professional skills, including teamwork, written and oral communications, problem-solving abilities, a commitment to lifelong learning, core ethical values, and an understanding of the implications of one’s work on society, and (3) prepared for practice in one of the fertile application areas where computing and other technical fields intersect through in-depth knowledge of at least one related engineering discipline or application area.

Undergraduate Study

Computer Science and Engineering B.S.

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

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

Preparation for the Major

Required: Chemistry and Biochemistry 20A; Computer Science 1, 31, 32, 33, 35L, M51A (or Electrical Engineering M16); Electrical Engineering 1, 2, 10; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 4AL, 4BL.

The Major

Required: Computer Science 101, 111, 118, 131, M151B (or Electrical Engineering M116C), M152A (or Electrical Engineering M116L), M152B (or Electrical Engineering M116D), 180, 181, Electrical Engineering 102, 110, 110L, 115A, 115C, Statistics 110A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three upper division computer science elective courses (12 units), one of which must be selected from Computer Science 143 or 161 or 174A. Electrical Engineering 103 may be substituted for one elective (credit is not given for both Computer Science 170A and Electrical Engineering 103), and either Computer Science 194 or one 4-unit 199 course may be applied as an elective by petition.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew06-07.pdf.

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.

Preparation for the Major

Required: Chemistry and Biochemistry 20A; Computer Science 1, 31, 32, 33, 35L, M51A (or Electrical Engineering M16); Electrical Engineering 1, 2, 10; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 4AL, 4BL.

The Major

Required: Computer Science 101, 111, 118, 131, M152B (or Electrical Engineering M116D), 180, 181, Electrical Engineering 102, 110, 110L, 115A, 115C, Statistics 110A; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three upper division science and technology courses (12 units) not used to satisfy other requirements, which may include three computer science courses, three courses to augment the breadth courses requirement, or three courses selected from one of the following: astronomy, atmospheric and oceanic sciences, biological chemistry, biomathematics, chemical and biomolecular engineering, chemistry and biochemistry, civil and environmental engineering, Earth and space sciences, economics, electrical engineering, information studies, linguistics, management, materials science and engineering, mathematics, mechanical and aerospace engineering, microbiology, immunology, and molecular genetics, molecular biology, molecular, cell, and developmental biology, physics – courses selected from outside the school must be approved by petition; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and six upper division computer science elective courses (24 units), two of which must be selected from Computer Science 143, 161, 174A and one of which must be from 112 or 170A or Electrical Engineering 103 (credit is not given for both Computer Science 170A and Electrical Engineering 103). Students who select Electrical Engineering 103 may not receive credit for Mathematics 151A under the science and technology electives; if students have not taken Computer Science 130, one elective course must be 132, and either Computer Science 194 or one 4-unit 199 course may be applied as an elective by petition.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew06-07.pdf.

Graduate Study

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

The following introductory information is based on the 2006-07 edition of Program
Computer Science M.S.

Course Requirements
Course Requirement. A total of nine courses is required for the M.S. degree, including a minimum of five graduate courses. No specific courses are required, but a majority of both the total number of formal courses and the total number of graduate courses must consist of courses offered by the Computer Science Department.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

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

- Group I: Four required courses or equivalent from Computer Science M51A, 143 or 180, M151B, 181.
- Group II: Two required courses or equivalent from Computer Science 111, 112 or 118, 131 or 132, 161, 170A or 174A.

In addition, for each degree students must complete at least one course per quarter for three quarters of Computer Science 201 with grades of Satisfactory. Competence in any or all courses may be demonstrated in one of three ways:

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

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

Thesis Plan. In the thesis plan, seven of the nine courses must be formal courses, including at least four from the 200 series, and three may be in the 100 or 200 series. The remaining two courses must be 598 courses involving work on the thesis.

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

Computer Science Ph.D.

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

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

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

- Group I: Four required courses or equivalent from Computer Science M51A, 143 or 180, M151B, 181.
- Group II: Two required courses or equivalent from Computer Science 111, 112 or 118, 131 or 132, 161, 170A or 174A.

In addition, for each degree students must complete at least one course per quarter for three quarters of Computer Science 201 with grades of Satisfactory. Competence in any or all courses may be demonstrated in one of three ways:

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

Written and Oral Qualifying Examinations
After mastering the body of knowledge defined in the three fields and passing the breadth requirement, students take a writ-
tenth qualifying examination. After passing the written qualifying examination, students should form a doctoral committee and prepare to take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

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

Fields of Study

Artificial Intelligence

Artificial intelligence (AI) is the study of intelligent behavior. While other fields such as philosophy, psychology, neuroscience, and linguistics are also concerned with the study of intelligence, the distinguishing feature of AI is that it deals primarily with information processing models. Thus the central scientific question of artificial intelligence is how intelligent behavior can be reduced to information processing. Since even the simplest computer is a completely general information processing device, the test of whether some behavior can be explained by information processing mechanisms is whether a computer can be programmed to produce the same behavior. Just as human intelligence involves gathering sensory input and producing physical action in the world, in addition to purely mental activity, the computer for AI purposes is extended to include sense organs such as cameras and microphones, and output devices such as wheels, robotic arms, and speakers.

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

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

1. **Problem Solving.** Analysis of tasks, such as playing chess or proving theorems, that require reasoning about relatively long sequences of primitive actions, deductions, or inferences
2. **Knowledge representation and qualitative reasoning.** Analysis of tasks such as commonsense reasoning and qualitative physics. Here the deductive chains are short, but the amount of knowledge that potentially may be brought to bear is very large
3. **Expert systems.** Study of large amounts of specialized or highly technical knowledge that is often probabilistic in nature. Typical domains include medical diagnosis and engineering design
4. **Natural language processing.** Symbolic, statistical, and artificial neural network approaches to text comprehension and generation

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

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

Computational Systems Biology

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

Subject Matter and Course Offerings

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

1. Integrated computational and biological approaches to organismic, cellular, and mechanism-level studies of biological, including biomedical, systems
2. Modeling and simulation of cancer and other disease processes: neural, neuroendocrine, immune, and metabolic systems
3. Pharmacokinetics (PK), pharmacodynamics (PD), and physiologically-based PK modeling (PBPK)
4. Optimization of clinical therapy models
5. Modeling methodology for life science research, including experiment design simulation and optimization
5. Software development for modeling and model selection, and for kinetic analysis of biological systems, with emphasis on expert systems, user-friendly interfaces and universally available world wide web based software systems

6. Integrated modeling and experimental research in physiology, pharmacology, biochemistry, genomics, bioinformatics and related fields, developing the interface between (theoretical) modeling and laboratory experimentation and data analysis

7. Computational cardiology

8. Genomics, proteomics, metabolomics, and microarray data modeling

Computer Networks

The computer networks field involves the study of computer networks of different types, in different media (wired, wireless), and for different applications. Besides the study of network architectures and protocols, this field also emphasizes distributed algorithms, distributed systems, and the ability to evaluate system performance at various levels of granularity (but principally at the systems level). In order to understand and predict systems behavior, mathematical models are pursued that lead to the evaluation of system throughput, response time, utilization of devices, flow of jobs and messages, bottlenecks, speedup, power, etc. In addition, students are taught to design and implement computer networks using formal design methodologies subject to appropriate cost and objective functions. The tools required to carry out this design include probability theory, queueing theory, distributed systems theory, mathematical programming, control theory, operating systems design, simulation methods, measurement tools, and heuristic design procedures. The outcome of these studies is 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. Design methodology

Resource Allocation

A central problem in the design and evaluation of computer networks deals with the allocation of resources among competing demands (e.g., wireless channel bandwidth allocation to backlogged stations). In fact, resource allocation is a significant element in most of the technical (and nontechnical) problems we face today.

Most of our resource allocation problems arise from the unpredictability of the demand for the use of these resources, as well as from the fact that the resources are geographically distributed (as in computer networks). The computer networks field encounters such resource allocation problems in many forms and in many different computer system configurations. Our goal is to find allocation schemes that permit suitable concurrency in the use of devices (resources) so as to achieve efficiency and equitable allocation. A very popular approach in distributed systems is allocation on demand, as opposed to prescheduled allocation. On-demand allocation is found to be effective, since it takes advantage of statistical averaging effects. It comes in many forms in computer networks and is known by names such as asynchronous time division multiplexing, packet switching, frame relay, random access, and so forth.

Computer Science Theory

Computer science is in large measure concerned with information processing systems, their applications, and the corresponding problems of representation, transformation, and communication. The computer science fields are concerned with different aspects of such systems, and each has its own "theoretical component" with appropriate models for description and analysis, algorithms for solving the related problems, and mathematical tools. Thus in a certain sense "computer science theory" involves all of computer science and participates in all disciplines.

The term theoretical computer science has come to be applied nationally and internationally to a certain body of knowledge emphasizing the interweaving themes of computability and algorithms, interpreted in the broadest sense. Under computability, one includes questions concerning which tasks can and cannot be performed by information systems of different types restricted in various ways, as well as the mathematical analysis of such systems, their computations, and the languages for communication with them. Under algorithms, one includes questions concerning (1) how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), (2) how efficiently a proposed system performs a task in terms of resources used, and (3) the limits on how efficiently a task can be performed. These questions are often addressed by first developing models of the relevant parts of an information processing system (e.g., the processors, their interconnections, their rules of operation, the means by which instructions are conveyed to the system, or the way the data is handled) or of the input/output behavior of the system as a whole. The properties of such models are studied both for their own interest and as tools for understanding the system and improving its performance or applications.

Computer System Architecture

Computer system architecture deals with

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

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

Emphasis of Computer Science Theory

- Design and analysis of algorithms
- Distributed and parallel algorithms
- Models for parallel and concurrent computation
- Online and randomized algorithms
- Computational complexity
- Automata and formal languages
- Cryptography and interactive proofs
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 networking, programming languages, and human-computer interface design.

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

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

**Software Systems**

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

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

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

**Facilities**

Departmental laboratory facilities for instruction and research include:

**Artificial Intelligence Laboratories**

**Artificial Intelligence Laboratory**

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

**Cognitive Systems Laboratory**

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

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

**UCLA Vision Laboratory**
The UCLA Vision Laboratory is used for computer vision research, in particular the processing of sensory information to retrieve mathematical models of the environment in order for machines to interact with it. Applications include shape analysis, visual motion analysis, visual recognition, 3-D reconstruction, and vision-based control (for instance, autonomous vehicle navigation). See http://vision.ucla.edu.

**Computational System Biology Laboratories**

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

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

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

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

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

**Computer Networks Laboratories**

**CENS Systems Laboratory**
The CENS Systems Laboratory is used for research on the architectural challenges posed by massively distributed, large-scale, physically coupled, and usually untethered and small-form-factor computing systems. Through prototype implementations and simulation, such issues as data diffusion protocols, localization, time synchronization, low-power wireless communications, and self-configuration are explored. See http://feecs.cs.ucla.edu.

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

**High-Performance Internet Laboratory**
The High-Performance Internet Laboratory is used for investigating high-performance quality of service (QoS) techniques in the Internet, including QoS routing in Internet domains, QoS fault-tolerant multicast, TCP congestion control, and gigabit network measurements. See http://www.cs.ucla.edu/NRL/hpi/.

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

**Wireless Adaptive Mobility Laboratory**
The Wireless Adaptive Mobility Laboratory is used for investigating wireless local-area networks (with specific interest in ad-hoc networks, vehicular networks, and personal-area networks) and the interaction between wired and wireless network layers, middleware, and applications. Activities include protocol development, protocol analysis and simulation, and wireless testbed experiments. See http://www.cs.ucla.edu/NRL/wireless/.

**Computer Science Theory Laboratories**

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

**Theory Laboratory**
The Theory Laboratory is used for developing theoretical foundations for all areas of computer science. Activities include fundamental research into algorithms, computational complexity, distributed computing, cryptography, hardware and software security, quantum computing, biological computing, machine learning, and computational geometry.

**Computer Systems Architecture Laboratories**

**Concurrent Systems Laboratory**
The Concurrent Systems Laboratory is used for investigating the design, implementation, and evaluation of computer systems that use state-of-the-art technology to achieve high performance and high reliability. Projects involve both software and hardware, and often focus on parallel and distributed systems in the context of general-purpose as well as embedded applications. See http://www.cs.ucla.edu/csd/research/labs/cscl/.

**Digital Arithmetic and Reconfigurable Architecture Laboratory**
The Digital Arithmetic and Reconfigurable Architecture Laboratory is used for fast digital arithmetic (theory, algorithms, and design) and numerically intensive comput-
ing on reconfigurable hardware. Research includes floating-point arithmetic, online arithmetic, application-specific architectures, and design tools. See http://arith.cs.ucla.edu

Embedded and Reconfigurable System Design Laboratory
The Embedded and Reconfigurable System Design Laboratory is used for studying reconfigurable cores in embedded systems that provide the required adaptability and reconfigurability, and the design and CAD aspects of low-power embedded systems. See http://er.cs.ucla.edu.

VLSI CAD Laboratory
The VLSI CAD Laboratory is used for computer-aided design of VLSI circuits and systems. Areas include high-level and logic-level synthesis, technology mapping, physical design, interconnect modeling and optimization of various VLSI technologies such as full-custom designs, standard cells, programmable logic devices (PLDs), multichip modules (MCMs), system-on-a-chip (SOCs), and system-in-a-package (SIPs). See http://cadlab.cs.ucla.edu.

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

Knowledge-Based Multimedia Medical Distributed Database Systems Laboratory
The Knowledge-Based Multimedia Medical Distributed Database Systems Laboratory is used for developing new methodologies to access multimedia (numeric, text, image/picture) data by content and feature rather than by artificial keys such as patient ID. See http://kme.cs.ucla.edu.

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

Multimedia Systems Laboratory
The Multimedia Systems Laboratory is used for research on all aspects of multimedia: physical and logical modeling of multimedia objects, real-time delivery of continuous multimedia, operating systems and networking issues in multimedia systems, and development of multimedia courseware. See http://www.mmml.cs.ucla.edu.

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

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

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

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

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

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

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

Hardware
Computing facilities range from large campus-operated supercomputers to a major local network of servers and workstations that are administered by the department computing facilities (DCF) or school network (SEASnet). The departmental research network includes at least 30 Sun servers and shared workstations, on the school's own ethernet TCP/IP local network. A wide variety of peripheral equipment is also part of the facility, and many more research-group workstations share the network; the total number of machines exceeds 700, the majority running the UNIX operating system. The network consists of switched 10/100/1000 ethernet to the desktop with a gigabit backbone connection. The department LAN is connected to the campus gigabit backbone. An 802.11b wireless network is also available to faculty, staff, and graduate students.

Administrative Structure
The central facilities and wide-area networking are operated by the campuswide Communications Technology Services. Access to the departmental and SEASnet machines is controlled so as to maximize the usefulness of these computers for education and research, but no direct charges are involved.

Technical Support Staff
The support staff consists of hardware and software specialists. The hardware laboratory supports network connections, configurations routers, switches, and network monitoring tools. The software group administers the department UNIX servers, providing storage space and backup for department users.
Faculty Areas of Thesis Guidance

Professors

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

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

Wesley W. Chu, Ph.D. (Stanford, 1966)
Distributed computing, distributed database, memory management, computer communications, performance measurement and evaluation for distributed systems and multiaccess packet-switched systems

Jason (Jingsheng) Cong, Ph.D. (Illinois, 1990)
Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing

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

Joseph J. DiStefano III, Ph.D. (UCLA, 1966)
Biocybernetics; computational systems biology; dynamic biosystems modeling, simulation, clinical therapy and experiment design optimization methodologies; pharmacokinetic (PK), pharmacodynamic (PD), and physiologically-based PK (PBPK) modeling; knowledge-based (expert) systems for life science research

Michael G. Dyer, Ph.D. (Yale, 1982)
Artificial intelligence; natural language processing, connectionist, cognitive, and animat-based modeling

Milos D. Ercegovac, Ph.D. (Illinois, 1975)
Application-specific architectures, digital computer arithmetic, digital design, low-power systems, reconfigurable systems

Deborah L. Estrin, Ph.D. (MIT, 1985)
Sensor networks, embedded network sensing, environmental monitoring, computer networks

Mario Gerla, Ph.D. (UCLA, 1973)
Wireless ad-hoc networks: MAC, routing and transport protocols, vehicular communications, peer-to-peer mobile networks, personal-area networks (Bluetooth and ZigBee), underwater sensor networks, Internet transport protocols (TCP, streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocol performance evaluation

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

Problem solving, heuristic search, planning in artificial intelligence

Multimedia systems, database systems, data mining

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

Jens Palsberg, Ph.D. (Aarhus U., Denmark, 1982)
Compilers, embedded systems, programming languages

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

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

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

Stepano Soatto, Ph.D. (Cali Tech, 1996)
Computer vision; shape analysis, motion analysis, texture analysis, 3-D reconstruction, vision-based control, computer graphics; image-based modeling and rendering; medical imaging: registration, segmentation, statistical shape analysis, autonomous systems: sensor-based control, planning non-linear filtering; human-computer interaction: vision-based interfaces, visibility, visualization

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 protocols

Professors Emeriti

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

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

Jack W. Carlyle, Ph.D. (UC Berkeley, 1961)
Communication, computation theory and practice, algorithms and complexity, discrete system theory, experimental and probabilistic systems

Gerald Estrin, Ph.D. (Wisconsin, 1951)
Computer systems architecture, methodology and supporting tools for design of concurrent systems, automatic 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 conger-clone systems, performance evaluation and design of distributed multiaccess packet-switching systems, wireless networks, mobile computing, 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. Melkonoff, Ph.D. (UCLA, 1955)
Programming languages, data structures, database design, relational models, simulation systems, robotics, computer-aided design and manufacturing, numerical-controlled machinery

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

Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems/signal processing

Associate Professors

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

Songwu Lu, Ph.D. (Illinois, 1999)
Integrated-service support over heterogeneous networks, e.g., mobile computing environments, Internet and ActiveNet: networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics

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

Yuval Tami, Ph.D. (UC Berkeley, 1985)
Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection networks and switches, multi-core architectures, reconfigurable systems

Song-Chun Zhu, Ph.D. (Harvard, 1996)
Computer engineering, embedded systems, programming and computing, vision and visual arts

Assistant Professors

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

Petros Faloutsos, Ph.D. (Toronto, 2002)
Computer graphics, computer animation

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

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

Programming language design, static type systems, formal methods, software model checking, compilers

Glen D. Reinman, Ph.D. (UC San Diego, 2001)
Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multicore and multiprocessor design

Senior Lecturer

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

† Also Professor of Medicine
‡ Also Professor of Mathematics
¶ Member of Brain Research Institute
33. Introduction to Computer Organization. (5) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced prerequisite: course 32. Introduction to course on computer architecture, assembly language, and operating systems fundamentals. Number systems, machine language, and assembly language. Procedure calls, stacks, interrupts, and traps. Assembly language programming. Organization, adaptation, low-level systems concepts: processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading. Mr. Palsberg, Mr. Smiallberg (F,Sp)

35L. Software Construction Laboratory. (2) Formerly numbered 35.) Laboratory, four hours; outside study, two hours. Requisite: course 31. Fundamentals of commonly used software tools and environments, particularly open-source tools to be used in upper division computer science courses. Letter grading. Mr. Eggert, Mr. Palsberg (F, W)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical Engineering M156.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Simple logic modules and programmable logic arrays. Implementation of algorithmic systems: data and control sections. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading. Mr. Ercogovac, Mr. Potkonjak (F, W, Sp)

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

101. Upper Division Computer Science Seminar. (1) Seminar, one hour. Discussion of and critical thinking about topics in computer science and engineering. Assignments given to bolster independent study and writing skills. Letter grading. Mr. Munzt (F)

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

19. Fiat Lux Freshman Seminar. (1) Seminar, one hour. Discussion of and critical thinking about topics in current research, emerging areas, and contemporary issues in computer science and engineering. Assignments given to bolster independent study and writing skills. Letter grading. Mr. Munzt (Sp)


112. Computer System Modeling Fundamentals. (4) Lecture, four hours; outside study, eight hours. Requisite: Statistics 110A. Designed for juniors/seniors. Probability and stochastic process models as applied in computer science. Basic methodological tools include random variables, conditional probabilities, expectation and higher moments, Bayes theorem, Markov chains. Applications include probabilistic algorithms, evidential reasoning, analysis of algorithms and data structures, reliability, computer communication protocols and queueing models. Letter grading. Mr. Gerla, Mr. Munzt (F, W)

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

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

118. Computer Network Fundamentals. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 32, 33. Highly recommended: course 111. Designed for juniors/seniors. Introduction to design and performance evaluation of computer networks, including, but not limited to, protocol stacks, high-speed LANs (IEEE802.11), and ad hoc and personal area networks (e.g., Bluetooth). Experimental laboratory sessions included. Letter grading. Mr. Gerla, Ms. Zhang (F, W, Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 111, 118. Introduction to fundamental data communication concepts underlying and supporting modern networks, with focus on physical and media access layers of network protocol stack. Systems include high-speed LANs (e.g., fast and giga Ethernet), optical DWDM (dense wavelength division multiplexing), time division SONET networks, wireless LANs (IEEE802.11), and ad hoc wireless and personal area networks (e.g., Bluetooth). Experimental laboratory sessions included. Letter grading. Mr. Eggert, Mr. Majumdar (W, Sp)

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

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 131, 191. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; theory of parsing. Letter grading. Mr. Eggert, Mr. Palsberg (F, W)

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

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

M151B. Computer System Architecture. (4) (Same as Electrical Engineering M116C.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 33, and M51A or Electrical Engineering M16. Recommended: courses 111, and M152A or Electrical Engineering M116L. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading.

Mr. Reinman, Mr. Tamir (F;Sp)


Mr. Ercegovac (F; odd years)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical Engineering M116L.) Laboratory, four hours; outside study, two hours. Requisite: course M51A or Electrical Engineering M16. Hands-on design, implementation, and debugging of digital logic circuits using programmable and firmware engineering. Use of design tools, schematic capture and simulation, implementation of complex circuits using programmed array logic, design projects. Letter grading.

Mr. Sarrafzadeh (F,W;Sp)

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

Mr. Sarrafzadeh (F,W;Sp)


Mr. Darwiche, Mr. Korf (F,W;Sp)


Mr. Parker (W)

M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Electrical Engineering M171L.) Laboratory, four to eight hours; outside study, two to four hours. Requisites: course M152A. Limited to seniors. Interpretation of analog-serial and symbolic computation, matrix algebra, statistics, floating point, optimization, and statistical analysis. Emphasis on applications in simulation of physical systems. Letter grading.

Mr. Galin, Mr. Meyerson (F,W;Sp)


Ms. Greibach, Mr. Ostrovsky, Mr. Sahai (F,W;Sp)

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

Mr. Ostrovsky (F; odd years)

M186A. Introduction to Cybernetics, Biomodeling, and Biomedical Computing. (2) (Formerly numbered M196A.) (Same as Biomedical Engineering CM186A and Computational and Systems Biology M186A.) Lecture, two hours. Requisites: Mathematics 31A, 31B, Program in Computing 10A. Strongly recommended for students with potential interest in biomedical engineering/computing. (Formerly numbered CM186L.) Introduction and survey of topics in cybernetics, biomodeling, biocomputing, and related bioengineering disciplines. Lectures presented by faculty currently performing research in one of the areas; some sessions include laboratory tours. P/NP grading.

Mr. DiStefano (F)

CM186B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered M186B.) (Same as Biomedical Engineering CM186B and Computational and Systems Biology M186B.) Lecture, four hours; laboratory, three hours. Concurrently scheduled with course CM286L. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multilayer, multiconductor, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286L. Letter grading.

Mr. DiStefano (F)

CM186L. Biomedical Systems/Biocybernetics Research Laboratory. (2 to 4) (Formerly numbered CM196L.) (Same as Biomedical Engineering CM186L and Computational and Systems Biology M196L.) Laboratory, four hours. Requisite: course CM186B. Special laboratory techniques and experience in biocybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Computation laboratory: experiment design and implementation, test cases and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM286L. Letter grading.

Mr. DiStefano (Sp)
188. Special Courses in Computer Science. (4) (Formerly numbered 198.) Lecture, four hours; outside study, eight hours. Special topics in computer science. Open to students that the instructor feels are capable of benefit, either on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with instructor change. Letter grading.

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

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

Graduate Courses

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

202. Advanced Computer Science Seminar. (4) Seminar. May be repeated for credit. Eight hours. Preparation for Ph.D. exam: introduction to complexity; function and design; introduction to major research areas; current research; current literature. Any member completes one tutorial and one or more original pieces of work in the specialized area. May be repeated for credit. Letter grading. Ms. Estrin (F,W,Sp)

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

212A. Queuing Systems Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: course 112. Designed for graduate students in the field of computer engineering. Probability; first order statistics; Markov processes; renewal theory. Letter grading. Ms. Estrin, Mr. Srivastava (F,Sp)

214. Data Transmission in Computer Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112. Limited to graduate computer science students. Discrete data streams, formats, rates, transductions; digital data transmission via analog signaling in computer communications; media characteristics, systems methodologies, performance analysis; modern designs; physical inter- faces in computer communication links; national/international standards; tests and measurements. Letter grading. Mr. Carlyle

215. Computer Communications and Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112. Designed for graduate students in the area of computer engineering. Probability, first order statistics, Markov processes, renewal theory. Letter grading. Ms. Estrin, Mr. Srivastava (F,Sp)

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 design in computer networks, including terrestrial distributed computer networks; satellite packet switching; radio packet switching; local network architecture and control; network coordination. Letter grading. Mr. Chu (F)

217. Internet Architecture and Protocols. (4) Lecture, four hours; outside study, eight hours. Requisite: course 118. Focus on mastering existing core set of Internet protocols, including IP, core transport protocols, routing protocols, DNS, NTP, and security protocols such as SSL/TLS, to understand principles behind design of these protocols, appreciate their design tradeoffs, and learn lessons from their operation. Letter grading. Ms. Zhang

217B. Advanced Topics in Internet Research. (4) (Formerly numbered 217.) Lecture, four hours; outside study, eight hours. Requisite: course 217A. Designed for graduate students. Overview of Internet development history and fundamental principles underlying TCP/IP protocol design. Discussion of current Internet research topics, including latest research results in routing protocols, transport protocols, network measurements, network security protocols, and clean-state approach to network architecture design. Fundamental issues in network protocol design and implementations. Letter grading. Ms. 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. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading.

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

230A. Models of Information and Computation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131, 181. Paradigms, models, frameworks, and problem solving; UML and 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

231. Types and Programming Languages. (4) Lecture, four hours. Requisites: course 131. Introduction to static type systems and their usage in programming language design and software reliability. Operational semantics, simply-typed lambda calculus, type soundness proofs, types for mutable references, types for exceptions. Parametric polymorphism, let-bound polymorphism, polymorphic type inference. Types for objects, subtyping, combining parametric polymorphism and subtyping. Types for modules, parameterized modules. Formal specification and implementation of variety of type systems, as well as readings from recent research literature on modern applications of type systems. Letter grading. Mr. Millstein (F)
240A. Databases and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143. Theoretical and technological foundation of intelligent Database Systems, which merge database technology, knowledge-based systems, and advanced programming environments. Rule-based knowledge representation, spatio-temporal reasoning, and logic-based declarative querying/programming are salient features of this technology. Other topics include object-relational systems and data mining techniques. Letter grading. Mr. Zaniolo (F)


241A. Object-Oriented and Semantic Database Systems. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisites: courses 143, 271A. Object-oriented database system architecture and functional components. Systems comparison. Commercial products. Database design, organization, indexing, and performance. Future directions. Other topics at discretion of instructor. Letter grading. Mr. Cardenas (W)

241B. Pictorial and Multimedia Database Systems. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisites: courses 143, 271A. Multimedia data: alphanumeric, long text, images, pictures, video, and voice. Multimedia information systems requirements. Data models and accessing. Querying, query languages, and communication. Database design and organization, logical and physical. Search by content and indexing methods. Internet multimedia streaming. Data heterogeneity and distribution. Other topics at discretion of instructor. Letter grading. Mr. Cardenas (W)

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

245A. Intelligent Information Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 241A, 255A. Knowledge discovery in database, knowledge-base maintenance, knowledge-base and database integration architectures, and scale-up issues and applications to cooperative database systems, intelligent decision support systems, and intelligent planning and scheduling systems; computer architecture for processing large-scale knowledge-base/database systems. Letter grading. Mr. Chu (Sp)

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

249. Current Topics in Data Structures. (2 to 12) Lecture, four hours; outside study, eight hours. Re-view of current literature in an area of data structures in which instructor has developed special proficiency as a consequence of research interests. May be repeated for credit with topic change. Letter grading.

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

251B. Parallel Computer Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. SIMD and MIMD systems, symmetric multiprocessors, distributed-shared-memory systems, messages-passing systems, clusters, interconnection networks, underlying hardware choices, operating systems, fault tolerant design, memory consistency, synchronization, and implementation. Letter grading. Mr. Ercegovac, Mr. Tamir (W)

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

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

253C. Testing and Testable Design of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Basic fault tolerant design for various problems in testing and testable designs of VLSI systems, including fault modeling, fault simulation, testing for single stuck faults and multiple stuck faults, functional testing, design for testability, compression techniques, and built-in self-test. Letter grading. Mr. Cong

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

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

256B. Design of VLSI Circuits and Systems. (4) (Same as Electrical Engineering 251B.) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisite: course M51A or Electrical Engineering M16, and Electrical Engineering 115A. Recommended: Electrical Engineering 115C. LSI/VLSI design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on a chip. Letter grading. Mr. Rennells

256B-M256C. LSI in Computer System Design. (4-4) (Same as Electrical Engineering 216B-M216C.) Lecture, four hours; laboratory, four hours. Letter grading. Mr. Kahng

256F. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Preparation: one course in analysis and design of algorithms. Basic theory of combinational optimization for VLSI design including: mathematical programming, network flows, matching, greedy and heuristic algorithms, and stochastic methods. Emphasis on practical application to computer-aided physical design of VLSI circuits at high-level phases of layout: partitioning, placement, graph folding, floorplanning, and global routing. Letter grading. Mr. Kahng

258F. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M51A, 180. Detailed study of various physical design automation problems of VLSI circuits, including logic partitioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven layout. Discussion of applications of a number of important optimization techniques, such as network flows, Steiner trees, simulated annealing, and genetic algorithms. Letter grading. Mr. Cong

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M51A, 180. Detailed study of various problems in the synthesis of VLSI digital systems, including two-level Boolean network optimization; multilevel Boolean network optimization; technology modeling for standard cell designs and field-programmable gate-array (FPGA) designs; retiming for sequential circuits; and applications of binary decision diagrams (BDDS). Letter grading. Mr. Cong

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M258A, 258F. Detailed study of various problems in analysis and design of high-speed VLSI interconnects at both integrated circuit (IC) and package levels, including interconnect resistance, impedance, loss, lossy transmission lines, crosstalk 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 system-level design architectures in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. Mr. Dyer (F)


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

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

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

262Z. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Letter grading. Mr. Pearl

262A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Introduction to natural language processing (NLP), with emphasis on semantics. Pre-processing tasks, such as parsing and resolution of ambiguity, inductive learning, modeling creativity, inductive learning by experience, role of episodic memory organization in learning. Examination of BACON, AM, Eurisko, HACKER, teachable production systems. Failure-driven learning. Letter grading. Mr. Dyer

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

267B. Artificial Neural Systems and Connectionist Computing. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Analysis of major connectionist computing paradigms and underlying models of biological and physical processes. Examination of past and current implementations of artificial neural networks along with their applications to associative knowledge processing, general multilayer pattern recognition including speed and vision, and adaptive robot control. Students required to prepare a research paper analyzing research in one area of interest. Letter grading. Mr. Vidal

268. Machine Perception. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Computational aspects of processing visual and other sensory information. Unified treatment of early vision in man and machine. Integration of symbolic and iconic representations of the image process and computational neuroscience. Neural networks and connectionism as a paradigm for parallel and concurrent computation in application to problems of perception, vision, multimodal sensory integration, and robotics. May be repeated for credit. S/U grading. Mr. Dyer

268S. Seminar: Computational Neuroscience. (2 to 4) Seminar, to be arranged. Review of current literature and research practice in an area of artificial intelligence in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. Mr. Dyer (F)
270A. Computer Methodology: Advanced Numerical Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 103 or Mathematics 151B or comparable experience with numerical computing. Designed for graduate computer science and engineering students. Principles of computer treatment of selected numerical problems in algebraic and differential systems, transformation and approximation, iterative methods, data acquisition and reduction; emphasis on concepts pertinent to modeling and simulation and the applicability of contemporary developments in numerical software. Computer exercises. Letter grading. Mr. Carlyle (F)


271C. Seminar: Advanced Simulation Methods. (2) Seminar; two hours outside study, six hours. Requisite: course 271A. Discussion of advanced topics in simulation and modeling of system 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 and validation of simulation models, development of analysis of systems, comparisons of alternative systems configurations. Variance reduction techniques, simulation models of computer systems and manufacturing systems. Letter grading.


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

M276A. Pattern Recognition and Machine Learning. (4) (Formerly numbered 276A.) (Same as Statistics M231.) Lecture, three hours. Recommended for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are used in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering, complexity (VC-dimension, MDL, AIC), PCA/CAT, MDS, SVM, boosting. S/U grading. Mr. Zhu

276B. Structured Computer Vision. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Methods for computer processing of image data. Systems, concepts, and algorithms for image analysis, radiologic and robotic applications. Letter grading. Mr. Klinger

276C. Speech and Language Communication in Artificial Intelligence. (4) Lecture, four hours; outside study, eight hours. Introduction to the topic of speech communication, with a focus on the role of language in AI. Letter grading. Mr. Klinger

279. Current Topics in Computer Science: Methodology. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in an area of computer science methodology in which instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. (F/W,Sp)

280A-280ZZ. Algorithms. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections from design, analysis, optimization, and implementation of algorithms; computational complexity and general theory of algorithms; algorithms for particular application areas. Substitutes of some current sections: Principles of Design and Analysis (280A); Distributed Algorithms (280Z). May be repeated for credit with consent of instructor and with topic change. Letter grading.

280AP. Approximation Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Background in discrete mathematics helpful. Theoretically sound techniques for dealing with NP-hard problems. Inability to solve these problems efficiently means algorithmic techniques are based on approximation — finding solution that is near to best possible in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include primal-dual method, linear program rounding, greedy algorithms, and local search. Letter grading. Mr. Meyerson (F)

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Background in discrete mathematics helpful. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable and recursively enumerable sets, closure properties, machine characterizations, nondeterminism, decidability, unsolvable problems, “easy” and “hard” problems, PTIME/NP-TIME. Letter grading. Mr. Greibach, Mr. Parker

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 181. Finite-state machines, transducers, and their generalizations; regular expressions, transduction expressions, realizability; decomposition, synthesis, and design considerations; topics in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, control, system modeling, and simulation. Letter grading. Mr. Carlyle

M282A. Cryptography. (4) (Formerly numbered 282A.) (Same as Mathematics M209A.) Lecture, four hours; outside study, eight hours. Introduction to the topic of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, public-key and private-key encryption, secret-sharing, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, key-agreement, contract signing, and two-party secure computation with static security. Letter grading. Mr. Ostrovsky (W)

M282B. Cryptographic Protocols. (4) (Formerly numbered 282B.) (Same as Mathematics M209B.) Lecture, four hours; outside study, eight hours. Requisite: course M282A. Consideration of advanced cryptographic protocol design and analysis. Topics include noninteractive zero-knowledge proofs; zero-knowledge arguments; concurrent and non-black-box zero-knowledge; IP=PSpace proof, stronger notions of security for public-key encryption, including chosen-ciphertext security; secure multiparty computation; dealing with dynamic adversary; nonmalleability and composability of secure protocols; software protection; threshold cryptography; identity-based cryptography; private information retrieval; extraction against man-in-the-middle attacks; voting protocols; identification protocols; digital cash schemes; lower bounds on use of cryptographic primitives, software obfuscation. May be repeated for credit with topic change. Letter grading. Mr. Ostrovsky (W)


284A-284ZZ. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 181. Additional requisites for each offering announced in advance by department. Selections from families of formal languages, grammars, automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Substitutes 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

CM286B. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Biomedical Engineering CM286B.) Lecture, four hours; laboratory, three hours. Corequisite: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control systems, multicompartamental, predator-prey, pharmacokinetics (PK), pharmacodynamics (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathway analysis), and organism levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, data modeling software and PC laboratory assignments. Concurrently scheduled with course CM186B. Letter grading. Mr. DiStefano (F)
Electrical Engineering

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C. Kumar N. Patel, Ph.D.
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Behzad Razavi, Ph.D.
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Paul K.C. Wang, Ph.D.
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Eli Yablonovitch, Ph.D. (Northrop Grumman Professor of Electrical Engineering)
Kung Yao, Ph.D.

Professors Emeriti
Frederick G. Allen, Ph.D.
Francis F. Chen, Ph.D. (Research Professor)
Robert S. Elliott, Ph.D.
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Dejan Markovic, Ph.D.
Sudhakar Pamarti, Ph.D.
Michaela van der Scharr, Ph.D.
Paulo Tabuada, Ph.D.
Yuanxun Ethan Wang, Ph.D.
Benjamin S. Williams, Ph.D.

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Mary Eshaghian-Wilner, Ph.D.
Michael P. Fitz, Ph.D.
Giorgio Franceschetti, Ph.D.
Joel Schulman, Ph.D.
Ming C. Wu, Ph.D.

Adjunct Associate Professors
Bijan Houshmand, Ph.D.
Ingrid M. Verbauwhede, Ph.D.

Adjunct Assistant Professor
Charles Chien, Ph.D.

Visiting Assistant Professor
Eran Socher, Ph.D.

Scope and Objectives
The Electrical Engineering Department emphasizes teaching and research in the fields of communications and telecommunication, control systems, magnetostatics, embedded computing systems, engineering optimization/operations, research, integrated circuits, and systems, microelectromechanical systems/nanotechnology (MEMS/nano), photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. In each of these fields, the department has state-of-the-art research programs and facilities exploring exciting new concepts and developments. The program grants one undergraduate degree (Bachelor of Science in Electrical Engineering) and two graduate degrees (Master of Science and Doctor of Philosophy in Electrical Engineering). The graduate program provides students with an opportunity to pursue advanced coursework, in-depth training, and research investigations in several fields.

Department Mission
The education and research activities in the Electrical Engineering Department are strongly aligned with its mission statement. In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental knowledge in electrical engineering who can provide leadership and service to California, the nation, and the world, (2) pursue creative research and new technologies in electrical engineering and across disciplines in order to serve the needs of industry, government, society, and the scientific community by expanding the body of knowledge in the field, (3) develop partnerships with industrial and government agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

Undergraduate Program Objectives
The ABET-accredited electrical engineering curriculum provides an excellent background for either graduate study or employment. In consultation with its constituents, the Electrical Engineering Department has set its educational objectives as follows: (1) fundamental knowledge, whereby program graduates are skilled in the fundamental concepts of mathematics, physical sciences, and electrical engineering necessary for success in industry, government service, or graduate school, (2) specialization, whereby program graduates are prepared to pursue career choices in electrical engineering, computer engineering, biomedical engineering, or related interdisciplinary fields that benefit from a strong background in engineering or applied sciences, (3) design skills, whereby program graduates are prepared with problem-solving skills, laboratory skills, and design skills for technical careers, (4) professional skills, whereby program graduates are prepared to thrive and to lead with a well-rounded education that includes communication and teamwork skills as well as an appreciation for ethical behavior, and (5) self-learning, whereby program graduates are prepared to continue their professional development through continuing education and personal development experiences based on their awareness of library resources and professional societies, journals, and meetings.
Undergraduate Study

Electrical Engineering B.S.

The undergraduate curriculum allows Electrical Engineering majors to specialize in one of three emphasis areas or options. The three options are structured as an electrical engineering degree, and the only degree offered to undergraduate students by the department is the Bachelor of Science degree in Electrical Engineering.

No distinction is made among the three options: (1) electrical engineering (EE) option is the regular option that provides students with preparation in electrical engineering with a range of required and elective courses across several disciplines; (2) computer engineering (CE) option provides students with preparation in embedded systems and software and hardware issues. Students replace some of the senior courses in the regular EE option with computer engineering-oriented courses or computer science courses; and (3) biomedical engineering (BE) option provides students with exposure to additional chemistry and life sciences courses and helps them meet most of the premedical preparation requirements so that they are prepared for careers in bioengineering, medicine, or electrical engineering.

Electrical Engineering Option

Preparation for the Major

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

The Major

Required: Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115AL, 121B, 131A, 132A, 141, 161, Mathematics 132, Statistics 105; three breadth courses (12 units), three major field elective courses from Electrical Engineering 115B or 123A or 124, CM150, and 163A or 173; one design course from 129D; and one laboratory course from 122L or CM150L (or by petition from 194 or 199)

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

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

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Biomedical Engineering Option

Preparation for the Major

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

The Major

Required: Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115AL, 131A, Mathematics 132, Statistics 105; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 units) selected from the biomedical engineering pathway as follows: three major field elective courses from Electrical Engineering 132A, 141, and 176 or Mechanical and Aerospace Engineering 105A; one design course from Electrical Engineering 113D or 114D or 180D; and one laboratory course from Biomedical Engineering CM186L or Electrical Engineering M171L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Computer Engineering Option

Preparation for the Major

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

The Major

Required:

Electrical Engineering 101, 102, 103, 110, 110L, 113, 115A, 115C, M116C (or Computer Science M151B), 131A, 132B or Computer Science 118, Mathematics 132, Statistics 105; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from the computer engineering pathway as follows: three major field elective courses from Computer Science 111, 117 or Electrical Engineering 132A, and 131 or 132 or 180; one design course from Electrical Engineering 113D, M116D, M116L, or 180D; and one laboratory course from Electrical Engineering M116L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Graduate Study

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

The following introductory information is based on the 2006-07 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the “Publications” link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.

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

Electrical Engineering M.S. Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis.

In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. A majority of the courses must be in or related to electrical engineering and belong to one of the specialized major fields described below.

Undergraduate Courses. Lower and upper division undergraduate courses required for any of the B.S. options in Electrical Engineering cannot be applied toward graduate degrees.

In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Communications and Telecommunications

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

Minimum Course Requirements. Nine 4-unit courses, of which at least six must be graduate courses.

Thesis Plan. Electrical Engineering 230A, 232A; two additional 200-level electrical engineering courses in the communications and telecommunications engineering area; three or more courses, of which at least two must be 200-level electrical engineering courses, subject to the approval of the student’s adviser. Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. The three courses in Group I must be selected from those listed below in Groups I and II, and at least four of the seven courses must be selected from Group II.

The remaining two courses may, subject to the approval of the student’s adviser, be selected as free electives from the 100 or 200 series in order to meet the overall requirements given above.

Comprehensive Examination Plan. At least seven courses must be selected from those listed below in Groups I and II, and at least four of the seven courses must be selected from Group II.

The remaining two courses may, subject to the approval of the student’s adviser, be selected as free electives from the 100 or 200 series in order to meet the overall requirements given above.


Embedded Computing Systems

Requisite: B.S. degree in Electrical Engineering or Computer Engineering.

Thesis Plan. Nine courses, of which at least six must be graduate courses, and a thesis. The three courses in Group I must be completed, and at least three courses
must be selected from Group II. The remaining three courses may be selected as free electives. Eight units (two courses) of Electrical Engineering 598 may be applied as free electives.

**Comprehensive Examination Plan.** Nine courses, of which at least six must be graduate courses. The three courses in Group I must be completed, and at least three courses must be selected from Group II. The remaining three courses may be selected as free electives.

Group I: Electrical Engineering 201A, M202A, 204A.


**Free Electives.** All 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser and major field chair. However, students are strongly encouraged to take these courses from allied major fields, such as communications and telecommunications, integrated circuits and systems, and signal processing. Undergraduate core courses may not be applied as free electives.

**Engineering Optimization/Operations Research.**

**Requisite.** B.S. degree in Engineering or Mathematical Sciences or equivalent.

**Minimum Course Requirements.** At least nine courses, of which at least five must be graduate courses. For the requisite structure, consult the department.

In consultation with an adviser, students may elect the thesis plan or the comprehensive examination plan. M.S. students in either plan must take at least three courses from Group I and at least two courses from Group II.

Group I: Optimization (Mathematical Programming): Electrical Engineering 232E, 236A, 236B, 236C.


**Thesis Plan.** Under the thesis plan, students must take 8 units (two courses) of Electrical Engineering 598 to cover the research work and preparation of the thesis. Only 4 of these units may be used to satisfy the graduate course requirement; however, the 8 units can be used to satisfy the total course requirement.

**Comprehensive Examination Plan.** Under the comprehensive examination plan, students may not apply any 500-level courses toward the course requirements.

**Integrated Circuits and Systems.**

**Requisite.** B.S. degree in Electrical Engineering or equivalent, with strong emphasis on circuit design. Coursework must have covered the material contained in Electrical Engineering 113, 115B, and 115C.

**Minimum Course Requirements.** Nine courses, of which at least six must be graduate courses. A thesis must be completed under the direction of a faculty adviser.

**Thesis Plan.** The three courses in Group I must be completed. In addition, three courses must be selected from Groups II and III with at most, one from Group III. The remaining three courses may be selected as free electives.

**Comprehensive Examination Plan.** Eleven graduate courses, including the three courses in Group I and at least six courses from Groups II and III, with no more than two courses from Group III. Two elective courses may be taken from any 200-level courses in the department. The courses must be taken for letter grades and are subject to the approval of the faculty adviser. Undergraduate courses may not be applied.

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


Group III: Computer Science 251A, 252A 253C.

**Free Electives.** With some exceptions, all 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser. However, it is strongly recommended that courses from the fields of communications and telecommunications, signal processing, and solid-state electronics be used as the free electives. Undergraduate core courses in the Electrical Engineering Department and HSSEAS may not be applied as free electives. Electrical Engineering 598 may be applied as one of the three electives.

The normal 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.

**Microelectromechanical Systems/Nanotechnology (MEMS/Nano).**

**Thesis Plan.** Under the thesis plan, students who complete only 4 units of course 598 are required to complete three elective courses (12 units), at least two of which must be graduate-level courses. Thesis-plan students who complete 8 units of course 598 are required to complete four elective courses (16 units), at least three of which must be graduate-level courses. Thesis-plan students who complete 8 units of course 598 are required to complete three elective courses (12 units), at least two of which must be graduate-level courses.

Group I: Electrical Engineering CM150, CM150L, CM250A, M250B.

Group II: Mechanical and Aerospace Engineering 281, 284.

**Free Electives.** All 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser and the chair of the MEMS/nanotechnology major field. Since the field of MEMS/nanotechnology is broadly applicable, students may take these courses from any of the other major fields in electrical engineering, as well as those fields of particular relevance to MEMS/nanotechnology that are outside the Electrical Engineering Department (e.g., mechanical engineering, materials science, bioengineering, chemical engineering, chemistry, physics). Undergraduate core courses may not be applied as free electives. An undergraduate course that is a requisite for a graduate
course may not be taken after the graduate course.

**Photonics and Optoelectronics**  
**Requisite.** B.S. degree in Engineering or Physics or equivalent.  
**Thesis Plan.** Electrical Engineering 270, 271, either 272 or 273 or 274, 598 (twice), and four additional courses, of which at least one must be a 200-level course.  
**Comprehensive Examination Plan.** Electrical Engineering 270, 271, either 272 or 273 or 274, and six additional courses, of which at least two must be 200-level courses.  
**Additional Courses.** With a few exceptions, all 100- and 200-level courses in the UCLA General Catalog are acceptable subject to the approval of the adviser. The exceptions are the following courses (which are not acceptable for any M.S. program in Electrical Engineering): (1) all school undergraduate core courses and (2) all department undergraduate core courses. Consult the departmental adviser for lists of the courses.

**Plasma Electronics**  
**Requisite.** B.S. degree in Engineering or Physics or equivalent.  
**Thesis Plan.** Electrical Engineering M185, 285A, 285B, 598 (twice), and four additional courses from the list below. Of these, at least two must be in the 200 series and at least one must be in electrical engineering. If Electrical Engineering M185 was taken as an undergraduate, it may be replaced by any engineering course on the list below.  
**Comprehensive Examination Plan.** Electrical Engineering M185, 285A, 285B, and six additional courses from the list below. Of these, at least three must be in the 200 series and at least one must be in electrical engineering. Of the remainder, at least one other course must be in engineering. If Electrical Engineering M185 was taken as an undergraduate, it may be replaced by any course on the list below. Other courses may be substituted with the consent of the department adviser.  

**Signal Processing**  
**Requisite.** B.S. degree in Electrical Engineering.  
**Minimum Course Requirements.** Nine 4-unit courses, of which at least seven must be graduate courses.  
**Thesis Plan.** A thesis must also be completed under the direction of a faculty adviser. Eight units (two courses) of Electrical Engineering 598 can be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses, but only one counts toward the seven graduate-level courses. The four courses in Group I must be completed, and at least two courses must be selected from Group II. The two courses from Group II may be substituted by other 200-level electrical engineering courses with the approval of the student’s faculty adviser. The remaining courses may be selected as free electives and/or Electrical Engineering 598.  
**Comprehensive Examination Plan.** The four courses in Group I must be completed, and at least two courses must be selected from Group II. The two courses from Group II may be substituted by other 200-level electrical engineering courses with the approval of the student’s faculty adviser. The remaining courses may be selected as free electives.  
**Group I.** Electrical Engineering 210A, 211A, 212A, M214A.  
**Group II.** Electrical Engineering 210B, 211B, 212B, 213A, 214B, M216A.  
**Free Electives.** All 100- and 200-level courses in the UCLA General Catalog are acceptable as free electives with the exception of undergraduate core courses in HSSEAS and undergraduate Electrical Engineering Department core courses. The choice of free electives must be approved by the faculty adviser.

**Solid-State Electronics**  
**Requisite.** B.S. degree in Engineering or equivalent.  
**Minimum Course Requirements.** Nine courses, of which at least five must be graduate courses. The program must include all core courses listed below with the remaining courses selected from the options list. Additional options may be applied with the consent of the adviser.  
Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses, but only one counts toward the five required graduate-level courses.  
**Solid-State Physical Electronics Requirements.** Core: Electrical Engineering 123B, 124, 223. Options: At least two courses from Electrical Engineering 221A, 221B, 221C, 224, and 225, with the remaining courses from graduate courses and those upper division courses that are not required for the B.S. degree in Electrical Engineering, with approval of the graduate adviser.  
**Semiconductor Device Physics and Design Requirements.** Core: Electrical Engineering 123B, 124, 221A, 221B. Options: At least two courses from Electrical Engineering 221C, 222, 223, 224, 225, and 298 (in solid-state electronics), with the remaining courses from graduate courses and those upper division courses that are not required for the B.S. degree in Electrical Engineering, with approval of the graduate adviser.

**Comprehensive Examination Plan**  
**Communications and Telecommunications**  
A written comprehensive examination is administered by the communications and telecommunications field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the communications and telecommunications field.  
**Control Systems**  
A written comprehensive examination, administered by a three-person committee chaired by a member of the controls field committee, must be taken during the last quarter of study toward the M.S. degree. In case of failure, students may be reexamined once with the consent of the graduate adviser.  
**Electromagnetics**  
A common six- to eight-hour comprehensive examination is offered once a year to students in this M.S. program. The examination must be taken during the academic year at the end of which students are expected to graduate. In case of failure, students may be reexamined once with the consent of the graduate adviser.  
**Embedded Computing Systems**  
Students are required to pass a written examination scheduled by the embedded computing systems field chair to be
concurrent with the Ph.D. preliminary examination.

**Engineering Optimization/Operations Research**

Students take a common written examination during their last quarter of coursework. The examination is normally offered at the end of Fall and Spring Quarters. In case of failure, students may be reexamined once with the consent of the graduate adviser.

**Integrated Circuits and Systems**

A written comprehensive examination is administered by the integrated circuits and systems field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the integrated circuits and systems field.

**Microelectromechanical Systems/Nanotechnology**

Students are required to pass a written examination scheduled by the microelectromechanical systems/nanotechnology (MEMS/nano) field chair to be concurrent with the Ph.D. preliminary examination.

**Photonics and Optoelectronics**

Consult the department. In case of failure of the comprehensive examination, students may be reexamined once with the consent of the graduate adviser.

**Plasma Electronics**

Consult the department. The majority of M.S. candidates proceed to the Ph.D. The Ph.D. qualifying examination may be taken to satisfy the M.S. comprehensive examination requirement.

**Signal Processing**

A written comprehensive examination is administered by the signal processing field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the signal processing field.

**Solid-State Electronics**

The comprehensive examination plan is not offered.

**Thesis Plan**

Consult the department for information on the thesis plan for the areas of communications and telecommunications, control systems, electromagnetics, engineering optimization/operations research, photonics and optoelectronics, and plasma electronics.

**Embedded Computing Systems**

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted concurrently with the coursework.

**Integrated Circuits and Systems**

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted in the Integrated Circuits and Systems Laboratory concurrently with the coursework.

**Microelectromechanical Systems/Nanotechnology**

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted concurrently with the coursework.

**Signal Processing**

A thesis must be completed under the direction of a faculty adviser.

**Solid-State Electronics**

A thesis is required. Consult the department for details.

**Electrical Engineering Ph.D.**

**Major Fields or Subdisciplines**

Communications and telecommunications; control systems; electromagnetics; embedded computing systems; engineering optimization/operations research; integrated circuits and systems; microelectromechanical systems/nanotechnology (MEMS/nano); photonics and optoelectronics; plasma electronics; signal processing; solid-state electronics.

**Course Requirements**

There is no formal course requirement for the Ph.D. degree, and students may theoretically substitute coursework by examination. Normally, however, students take courses to acquire the knowledge needed for the required written and oral preliminary examinations. The basic program of study for the Ph.D. degree is built around one major field and two minor fields. A detailed syllabus describing each major field can be obtained in the department office. The major field has a scope corresponding to a body of knowledge contained in six courses, at least four of which are graduate courses, plus the current literature in the area of specialization. Each major field named above is described in a Ph.D. major field syllabus. Each minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. Grades of B—or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor fields are usually selected to support the major field and are usually subsets of other major fields.

**Written and Oral Qualifying Examinations**

The written qualifying examination is known as the Ph.D. preliminary examination in HSSEAS. After mastering the body of knowledge defined in the major field, students take a preliminary examination in the major field. The examination typically consists of both a written part and an oral part, and students pass the entire examination and not in parts. The oral part does not exceed two hours and in some major fields is not required at all. Students who fail the examination may repeat it once only, subject to the approval of the major field committee. The major field examination, together with the three courses in a minor field, should be completed within six quarters after admission to the Ph.D. program. After passing the written qualifying examination described above, students take the University Oral Qualifying Examination, which should occur within three quarters after completing the written examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

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

**Fields of Study**

**Communications and Telecommunications**

Communications and telecommunications research is concerned with communications, telecommunications, networking,
and information processing principles and their engineering applications. Communications research includes satellite, spread spectrum, and digital communications systems. Fast estimation, detection, and optimization algorithms and processing techniques for communications, radar, and VLSI design are studied. Research is conducted in stochastic modeling of telecommunications engineering systems, switching, architectures, queueing systems, computer communications networks, local-area/metropolitan-area/long-haul communications networks, optical communications networks, packet-radio and cellular radio networks, personal communications systems, multimedia communications, and multuser resource management using game theory. 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 and hybrid control systems, with applications to autonomous systems, smart structures, flight systems, micro-robotics, microelectromechanical systems, and distributed networks.

Electromagnetics
Research in electromagnetics is conducted on novel integrated three-dimensional microwave and millimeter wave circuits, components, and systems, printed antennas, wireless and personal communications, fiber optics, integrated optics and photonic bandgap wave-guiding structures, left-handed transmission structures, antenna theory and design, satellite antennas, smart antennas and materials, antennas and biological tissue interactions, modern antenna near field measurement techniques, antenna diagnostics, radar cross section, multiple scattering, genetic algorithms, ultra wideband radar, radar signal processing, time domain electromagnetics, 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 nano-electronic computation, quantum information processing, fault-tolerant computation, combinatorics and information theory, advanced statistical processing, adaptive algorithms, dynamic circuits to implement configurable computing systems, low-power processor and system design, multimedia and communications processing, and all techniques for leveraging instruction-level parallelism.

Engineering Optimization/Operations Research
Engineering optimization/operations research is conducted in optimization theory, including linear and nonlinear programming, convex optimization and engineering applications, numerical methods, nonconvex programming, and associated network flow and graph problems. Another area of study is that of stochastic processes, including renewal theory, Markov chains, stochastic dynamic programming, and queueing theory. Applications are made to a variety of engineering design problems, including communications and telecommunications.

Integrated Circuits and Systems
Students and faculty in integrated circuits and systems (IC&S) are engaged in research on communications and RF integrated circuit design; analog and digital signal processing microsystems; integrated micro-sensors and associated low-power microelectronics; reconfigurable computing systems; and multimedia and communications processors. Current projects include wireless transceiver integrated circuits, including RF and baseband circuits; high-speed data communications integrated circuits; A/D and D/A converters; and digital processor design. M.S. and Ph.D. degrees require a thesis based on an ongoing IC&S project and full-time presence on campus. More information is at http://www.icsl.ucla.edu.

Microelectromechanical Systems/Nanotechnology
The microelectromechanical systems/nanotechnology (MEMS/nano) program is one of the most multidisciplinary research programs in the school, with faculty and student participation from the Departments of Electrical Engineering, Mechanical and Aerospace Engineering, Materials Science and Engineering, Chemical and Bio-molecular Engineering, and Biomedical Engineering. Inside the Electrical Engineering Department, the program has attracted students from solid-state electronics, integrated circuits and systems, photonics and optoelectronics, electromagnetics, computer engineering, and control systems. MEMS/nano research at UCLA emphasizes the design, fabrication, and physics of sensors, actuators, and systems on a nanometer to millimeter scale. Research project areas include micro/nano devices for sensing and actuation applications, biology and medicine (BioMEMS/NEMS), neuroengineering, reconfigurable electromagnetic systems (RF MEMS/NEMS, millimeter wave devices, antennas), fluid dynamics, distributed sensor and actuator networks, and MEMS/NEMS integrated with state-of-the-art integrated circuits.

Photonics and Optoelectronics
The photonics and optoelectronics group conducts research on photonic and optoelectronic devices, circuits, and systems. Target applications include but are not limited to telecommunication, data communication, phased array antenna systems, radar, CATV and HFC networks, and biomedicine. Among technologies being developed are nonlinear optical devices, ultrafast photodetectors and modulators, infrared detectors, mode-locked lasers, photonic bandgap devices, DWDM, CDMA, true time delay beam steering, temporal manipulation techniques and data conversion, digital and analog transceivers, optical MEMS, and biomedical sensors. Laboratory facilities host the latest technology in lasers, optical measurements, Gbit/s bit error rate testing, and
millimeter wave optoelectronic characterization. UCLA photonics hosts several national research centers and is a member of the Optoelectronic Industry Development Association (OIDA).

**Plasma Electronics**

Plasma electronics research is concerned with a basic understanding of both initially confined and magnetically confined fusion plasmas, as well as with the applications of plasma physics in areas such as laser plasma accelerators, ion beam sources, plasma-materials processing, and free-electron lasers. Extensive laboratory facilities are available, including high-power lasers and microwave and millimeter wave sources and detectors, a state-of-the-art laser and beam physics laboratory for advanced accelerator studies, and large quiescent low-density plasmas for nonlinear wave studies. In addition, experiments are conducted at a variety of national laboratories.

**Signal Processing**

Signal processing encompasses the techniques, hardware, algorithms, and systems used to process one-dimensional and multidimensional sequences of data. Research being conducted in the signal processing group reflects the broad interdisciplinary nature of the field today. Areas of current interest include analysis, synthesis, and coding of speech signals, video signal processing, digital filter analysis and design, multirate signal processing, image compression, adaptive filtering, communications signal processing, equalization techniques, synthetic aperture radar remote sensing, signal processing for hearing aids, auditory system modeling, automatic speech recognition, wireless communication, digital signal processor architectures, and the characterization and analysis of three-dimensional time-varying medical image data. The M.S. program includes a thesis project or a comprehensive examination.

**Solid-State Electronics**

Solid-state electronics research involves studies of new and advanced devices with picosecond switching times and high-frequency capabilities up to submillimeter wave ranges. Topics being investigated are hot electron transistors, quantum devices, heterojunction bipolar transistors, HEMTs, MESFETs, ultra-scaled MOSFETs, SOI devices, bipolar devices, and photovoltaic devices. The studies of basic materials, submicron structures, and device principles range from Si, Si-Ge, Si-SiCides, 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 standalone configurations are supported as well. Furthermore, this network connects to mainframes and supercomputers provided by the Henry Samueli School of Engineering and Applied Science and the Office of Academic Computing, as well as off-campus supercomputers according to need. The rapidly growing department-wide network comprises about 500 computers. These include about 200 workstations from Sun, HP, and SGI, and about 300 PCs, all connected to a 100 Mbit/s network with multiple parallel T3 lines running to individual research laboratories and computer rooms. The server functions are performed by several high-speed, high-capacity RAID servers from Network Appliance and IBM which serve user directories and software applications in a unified transparent fashion. All this computing power is distributed in research laboratories, computer classrooms, and open-access computer rooms.

**Research Centers and Laboratories**

**Center for High-Frequency Electronics**

The Center for High-Frequency Electronics has been established with support from several governmental agencies and contributions from local industries, beginning with a $10 million grant from Hewlett-Packard.

The first major goal of the center is to combine, in a synergistic manner, five areas of research. These include (1) solid-state millimeter wave devices, (2) millimeter systems for imaging and communications, (3) millimeter wave high-power sources (gyrotrons), (4) GaAs gigabit logic systems, and (5) VLSI and LSI based on new materials and structures. The center supports work in these areas by providing the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations into new electronic devices. Students, both graduate and undergraduate, receive training and instruction in a unique facility.

The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different interdependent fields. The Electrical Engineering Department, other departments within UCLA, and local universities...
(such as Cal Tech and USC) have begun to combine and correlate certain research programs as a result of the formation of the center.

**Circuits Laboratories**

The Circuits Laboratories are equipped for measurements on high-speed analog and digital circuits and are used for the experimental study of communication, signal processing, and instrumentation systems. A hybrid integrated circuit facility is available for rapid mounting, testing, and revision of miniature circuits. These include both discrete components and integrated circuit chips. The laboratory is available to advanced undergraduate and graduate students through faculty sponsorship on thesis topics, research grants, or special studies.

**Electromagnetics Laboratories**

The Electromagnetics Laboratories involve the disciplines of microwaves, millimeter waves, wireless electronics, and electromechanics. Students enrolled in microwave laboratory courses, such as Electrical Engineering 164D and 164L, special projects classes such as Electrical Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: (1) integrated microwave circuits and antennas, (2) integrated millimeter wave circuits and antennas, (3) numerical visualization of electromagnetic waves, (4) electromagnetic scattering and radar cross-section measurements, and (5) antenna near field and diagnostics measurements.

**Nanoelectronics Research Facility**

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

**Photonics and Optoelectronics Laboratories**

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

**Plasma Electronics Facilities**

Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art table top terawatt (T) 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, fociusable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS; other equipment includes a theta-pinch plasma generator, an electron linac injector, and electron detectors and analyzers. A second group of laboratories is dedicated to basic research in plasma sources for basic experiments, plasma processing, and plasma heating.

**Solid-State Electronics Facilities**

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

**Multidisciplinary Research Facilities**

The department is also associated with several multi-disciplinary research centers including:

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

**Faculty Groups and Laboratories**

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

- Adaptive Systems Laboratory (Sayed)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
• Autonomous Intelligent Networked Systems (Rubin)
• CMOS Research Laboratory (Woo)
• Communication Circuits Laboratory (Razavi)
• Complex Networks Group (Roychowdhury)
• Design Automation Laboratory (He)
• Device Research Laboratory (K. Wang)
• Digital Microwave Laboratory (E. Wang)
• Flight Systems Research Center (Balakrishnan)
• High-Performance Mixed Mode Circuit Design Group (Yang)
• High-Speed Electronics Laboratory (Chang)
• Image Communications Laboratory (Villasenor)
• Integrated Circuits and Systems Laboratory (Abidi)
• Laser-Plasma Group (Joshi)
• Microfabrication Laboratory (Judy)
• Microsystems Research Laboratory (Judy)
• Microwave Electronics Laboratory (Itoh)
• Millimeter Wave and Optoelectronics Laboratory (Fetterman)
• Nanoelectronics Research Center (Judy; Franz)
• Networked and Embedded Systems Laboratory (Srivastava)
• Neuroengineering Research Laboratory (Judy)
• Optoelectronics Circuits and Systems Laboratory (Jalali)
• Optoelectronics Group (Yablonovitch)
• Proactive Medianet Laboratory (van der Schaar)
• Speech Processing and Auditory Perception Laboratory (Alwan)
• Wireless Integrated Systems Research Group (Daneshrad)

Faculty Areas of Thesis Guidance

Professors
Asad A. Abidi, Ph.D. (UC Berkeley, 1981)
  High-performance analog electronics, device modeling
Abeer A.H. Alwan, Ph.D. (MIT, 1992)
  Speech processing, acoustic properties of speech sounds with applications to speech synthesis, recognition by machine and coding, hearing-aid design, and digital signal processing
A.V. Balakrishnan, Ph.D. (USC, 1954)
  Control and communications, flight systems applications
Frank M.C. Chang, Ph.D. (National Chiao-Tung, Taiwan, 1979)
  High-speed semiconductor (GaAs, InP, and Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications
Panagiotis D. Christofides, Ph.D. (Minnesota, 1996)
  Process modeling, dynamics and control, computational and applied mathematics
Babak Daneshrad, Ph.D. (UCLA, 1993)
  Digital VLSI circuits: wireless communication systems, high-performance communications integrated circuits for wireless applications
Deborah L. Estrin, Ph.D. (MIT, 1985)
  Sensor networks, embedded network sensing, environmental monitoring, computer networks
Harold R. Fetterman, Ph.D. (Cornell, 1968)
  Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state microwave structures and systems, biomedical applications of lasers
Warren S. Grundfest, M.D., FACS (Columbia U., 1980)
  Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms
Tatsuo Itoh, Ph.D. (Illinois, Urbana, 1969)
  Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas, photonic bandgap structures and meta materials applications; active integrated antennas, smart antennas; RF technologies for reconfigurable front-ends; sensors and transponders
Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)
  Operations research, mathematical programming, nonlinear programming, applications of mathematical programming to engineering and engineering/economic systems
Rajeev Jain, Ph.D. (Katholieke U., Leuven, Belgium, 1989)
  Design of digital communications and digital signal processing circuits and systems
Bahram Jalali, Ph.D. (Columbia U., 1989)
  RF photonics, integrated optics, fiber optic integrated circuits
  Laser fusion, laser acceleration of particles, nonlinear optics, high-power lasers, plasma physics
William J. Kaiser, Ph.D. (Wayne State, 1983)
  Research and development of new microsensor and microinstrument technology for industry, science, and biomedical applications; development and applications of new atomic-resolution scanning probe microscopy methods for microelectronic device research
Alan Laub, Ph.D. (Minnesota, 1974)
  Numerical linear algebra, numerical analysis, condition estimation, computer-aided control system design, high-performance computing
Jia-Ming Liu, Ph.D. (Harvard, 1982)
  Nonlinear optics, ultrastable optics, laser chaos, semiconductor lasers, optoelectronics, photonics, nonlinear and ultrafast processes
Warren B. Mori, Ph.D. (UCLA, 1987)
  Laser and charged particle beam-plasma interactions, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics
  Scientific computing, applied mathematics
Dee-Son Pan, Ph.D. (Cal Tech, 1977)
  New semiconductor devices for millimeter and RF power generation and amplification, transport in small geometry semiconductor devices, generic device modeling
T.C. Kumar N. Patel, Ph.D. (Stanford, 1961)
  Quantum electronics; non-linear optics, photoacoustics in gases, liquids, and solids; ultra-low level detection of trace gases; chemical and toxic gas sensors
Gregory J. Pottie, Ph.D. (McMaster, 1988)
  Communication systems and theory with applications to wireless networks
Yahya Rahmat-Samii, Ph.D. (Illinois, 1975)
  Satellite communications antennas, personal communication antennas including human interactions, antennas for remote sensing and radio astronomy applications, advanced numerical and genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory
Behzad Razavi, Ph.D. (Stanford, 1992)
  Analog, RF, and mixed-signal integrated circuit design, dual-standard RF transceivers, phase-locked systems and frequency synthesizers, A/D and D/A converters, high-speed data communication circuits
Wvani 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, multimedia IP networks, UAV/UGV-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering
Henry Samueli, Ph.D. (UCLA, 1980)
  VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design
Ali H. Sayed, Ph.D. (Stanford, 1992)
  Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems
Jeff S. Shamma, Ph.D. (MIT, 1988)
  Feedback control theory and design with applications to mechanical, aerospace, and manufacturing systems

* Also Professor of Mathematics
† Also Professor of Physics
**Kung Yao, Ph.D. (Princeton, 1965)**

**Eli Yablonovitch, Ph.D. (Harvard, 1972)**

**John D. Villasenor, Ph.D. (Stanford, 1989)**

**Lieven Vandenberghe, Ph.D. (Katholieke U., Leuven, Belgium, 1992)**

**Oscar M. Stafsudd, Ph.D. (UCLA, 1967)**

**Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)**

**82**

**Francis F. Chen, Ph.D. (Harvard, 1954)**

**Professors Emeriti**

**Jason L. Speyer, Ph.D. (Harvard, 1968)**

Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

**Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)**

Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

**Oscar M. Stafsudd, Ph.D. (UCLA, 1967)**

Quantum electronics: i.r. lasers and nonlinear optics; solid-state: i.r. detectors

**Lieuwen Vandenberghe, Ph.D. (Katholieke U., Leuven, Belgium, 1992)**

Optimization in engineering and applications in systems and control, circuit design, and signal processing

**John D. Villasenor, Ph.D. (Stanford, 1989)**

Communications, signal and image processing, configurable computing systems, and design environments

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

Nanoelectronics and optoelectronics, nano and molecular devices, MBE and superlattices, microwave and millimeter electronics, quantum information

**Paul K. C. Wang, Ph.D. (UC Berkeley, 1960)**

Control theory, modeling and control of nonlinear distributed-parameter systems with applications to micro-opto-electromechanical systems, micro and nano manipulation systems, control and coordination of multiple microspacecraft in formation

**Richard D. Wesel, Ph.D. (Stanford, 1996)**

Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes; joint algorithms for distributed communication and detection

**Alan N. Willson, Jr., Ph.D. (Syracuse, 1967)**

Theory and application of digital signal processing including VLSI implementations, digital filter design, nonlinear circuit theory

**Jason C. S. Woo, Ph.D. (Stanford, 1987)**

Solid-state technology, CMOS and bipolar device/circuit optimization, novel device design, modeling of integrated circuits, VLSI fabrication

**Eli Yablonovitch, Ph.D. (Harvard, 1972)**

Optoelectronics, high-speed optical communications, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication

**Kung Yao, Ph.D. (Princeton, 1965)**

Communication theory, signal and array processing, sensor system, wireless communication systems, VLSI and systolic algorithms

**Professors Emeriti**

**Frederick G. Allen, Ph.D. (Harvard, 1956)**

Semiconductor physics, solid-state devices, surface physics

**Francis F. Chen, Ph.D. (Harvard, 1954)**

Radiofrequency plasma sources and diagnostics for semiconductor processing

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

Electromagnetics

**Nhan N. Levan, Ph.D. (Monash U., Australia, 1966)**

Control systems, stability and stabilizability, errors in dynamic systems, signal analysis, wavelets, transform and applications

**Frederick W. Schott, Ph.D. (Stanford, 1949)**

Electromagnetics, applied electromagnetics

**Gabor C. Temes, Ph.D. (Ottawa, 1961)**

Analog MOS integrated circuits, signal processing, analog and digital filters

**Chand R. Viswanathan, Ph.D. (UCLA, 1964)**

Semiconductor electronics: VLSI devices and technology, thin oxides; reliability and failure physics of MOS devices; process-induced damage, low-frequency noise

*Donald M. Wiberg, Ph.D. (Cal Tech, 1965)**

Identification and control, especially of aerospace, biomedical, mechanical, and nuclear processes, modeling and simulation of respiratory and cardiovascular systems

**Jack Willis, B.Sc. (U. London, 1945)**

Active circuits, electronic systems

**Associate Professors**

**Lei He, Ph.D. (UCLA, 1999)**

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

**Jack W. Judy, Ph.D. (UC Berkeley, 1996)**

Microelectromechanical systems (MEMS), micromachining, microsensors, microactuators, and Microsystems; neuroengineering; electronic interfaces, neuroMEMS, implantable electronic systems, wireless telemetry, neural prostheses, and magnetism and magnetic materials

**Fernando G. Paganini, Ph.D. (Cal Tech, 1996)**

Robust and optimal control, distributed control, control communication networks, power systems

**C.-K. Ken Yang, Ph.D. (Stanford, 1998)**

High-performance VLSI design, digital and mixed-signal circuit design

**Assistant Professors**

**Dejan Markovic, Ph.D. (UC Berkeley, 2006)**

Power/area-efficient digital integrated circuits, VLSI architectures for wireless communications, organization methods and supporting CAD flows

**Christoph Niemann, Ph.D. (U. Technology, Darmstadt, Germany, 2002)**

Plasma physics in the context of thermonuclear fusion, laser and charged particle beam-plasma interaction, high-energy density science, plasma and particle-beam diagnostics

**Sudhakar Pamarti, Ph.D. (UC San Diego, 2003)**

Mixed-signal IC design, signal processing and communication theory

**Paulo Tabuada, Ph.D. (Technical University of Lisbon, Portugal, 2002)**

Real-time, networked, embedded control systems; mathematical systems theory including discrete-event, timed, and hybrid systems; geometric nonlinear control; algebraic/ categorical methods

**Michaela von der Schaar, Ph.D. (Eindhoven U. of Technology, Darmstadt, Germany, 2001)**

Multimedia processing and compression, multimedia networking, multimedia communications, multimedia architectures, enterprise multimedia, streaming, mobile and ubiquitous computing

**Yuanxun Ethan Wang, Ph.D. (Texas, Austin, 1999)**

Smart antennas, RF and microwave power amplifiers, numerical techniques, DSP techniques for microwave systems, phased arrays, wireless and radar systems, microwave integration; propagation, remote sensing

**Benjamin Williams, Ph.D. (MIT, 2003)**

Development of terahertz quantum cascade lasers

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*Also Professor Emeritus of Anesthesiology

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**Adjunct Professors**

**Nicolaos G. Alexopoulos, Ph.D. (Michigan, 1968)**

Integrated microwave and millimeter wave circuits and antennas, substrate materials and thin films, electromagnetic theory

**Elliott R. Brown, Ph.D. (Cal Tech, 1985)**

Ultrafast electronics and optoelectronics, microwave and power electronics, infrared and RF sensors and materials, biomedical and remote chem-bio sensors

**Michael P. Fitz, Ph.D. (USC, 1989)**

Physical layer communication theory and implementation with applications in wireless systems

**Giorgio Franceschetti, Ph.D. (Higher Institute of Telecommunications, Rome, 1961)**

Electromagnetic radiation and scattering, nonlinear propagation, synthetic aperture radar processing

**Joel Schulman, Ph.D. (Cal Tech, 1979)**

Semiconductor super lattices, solid-state physics

**Mary Estahgian-Wilner, Ph.D. (USC, 1998)**

Nanoscale architectures, bioinformatics networks, heterogeneous computing, mapping and scheduling paradigms, optical interconnects, VLSI and reconfigurable chips, parallel algorithms for image processing

**Ming C. Wu, Ph.D. (UC Berkeley, 1988)**

MEMS, micro-opto-electromechanical systems (MOEMS), optoelectronics, RF photonics, optical communications

**Adjunct Associate Professors**

**Bijan Houshand, Ph.D., (Illinois, Urbana, 1990)**

Computational electromagnetics, microwave imaging, and remote sensing

**Ingrid M. Verbaa, Ph.D., (Katholieke U., Leuven, Belgium, 1991)**

Embedded systems, VLSI architecture and circuit design and design methodologies for applications in security, wireless communications and signal processing

**Adjunct Assistant Professor**

**Charles Chien, Ph.D. (UCLA, 1995)**

End to end radio systems for high-speed adaptive wireless multimedia communications, multiband adaptive front-end and digital baseband transceiver architectures, and digital baseband transceiver integrated circuits for low-power high-performance applications

**Lower Division Courses**

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

   **Mr. Fetterman, Mr. Iohn (F,W,Sp)**

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

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

10. Circuit Analysis I. (4) Lecture; three hours; discussion; one hour; outside study, eight hours. Requisites: course 1 or Physics 1C, Mathematics 33A, 33B. Introduction to linear circuit analysis. Resistive circuits, Kirchhoff laws, operational amplifiers, node and loop analysis, Thévenin 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,Sp,Sw)

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

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

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

Upper Division Courses

100. 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 quantites, linear circuit principles, signal waveform, frequency analysis, transient and steady state circuit behavior, semiconductors and transistors, small signal models, and operational amplifiers. Letter grading. Mr. Razavi (F,Sp)

101. Engineering Electromagnetics. (4) Lecture, four hours; discussion; one hour; outside study, seven hours. Requisites: course 1 or Physics 1C, Mathematics 32A and 32B, or 33A and 33B. Electromagnetic field concepts, waves and phasors, transmission lines and Smith chart, transient responses, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading. Mr. Rahmat-Samii (F,Sw)


103. Applied Numerical Computing. (4) Lecture, three hours; discussion; one hour; outside study, eight hours. Requisites: Civil Engineering 15 or Computer Science 31 or Mechanical and Aerospace Engineering 20, Mathematics 33A, 33B (33B may be taken concurrently). Introduction to numerical computing and analysis. Floating point representation and round-off error; numerical solution of linear equations; methods for systems of nonlinear equations. Introduction to numerical optimization: least squares, with applications to interpolation, approximation, and numerical integration; linear programming. Letter grading. Mr. Jacobsen (F,Sw,Sp)

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

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

113. Digital Signal Processing. (4) Lecture, four hours; discussion; one hour; outside study, seven hours. Requisites: courses 112 or 113. Real-time implementation of digital signal processing algorithms on digital computer processors. Experiments involving A/D and D/A conversion, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for communications, speech, audio, or video using DSP chip. Letter grading. Ms. Alwan, Mr. Sayed (F,Sw,Sp)

113D. Digital Signal Processing Design. (4) Formerly numbered 113L. Laboratory, four hours; outside study, four hours. Requisite: course 113. Real-time implementation of digital signal processing algorithms on digital computer processors. Experiments involving A/D and D/A conversion, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for communications, speech, audio, or video using DSP chip. Letter grading. Ms. Verbauwhede (F,Sp)

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


115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. Requisites: courses 110L, 115A. Experimental determination of device characteristics, resistive diode circuits, single-stage amplifiers, compound transistor stages, effect of feedback on single-stage amplifiers. Letter grading. Mr. C.K. Yang (F,Sw,Sp)

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

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

115C. Digital Electronic Circuits. (4) Lecture, three hours; outside study, one hour; outside study, eight hours. Requisites: course 115A, Computer Science M51A. Recommended: course 115B. Transistor-level digital circuit analysis and design. Modern logic families (TTL, ECL, NMOS, CMOS), integrated circuit (IC) layout, MSI digital circuits (flipflops, registers, counters, PLAs, etc.), computer-aided simulation of digital circuits. Letter grading. Mr. Verbauwhede (F,Sw,Sp)


M116C. Computer Systems Architecture. (4) (Same as Computer Science M151B.) Lecture, four hours; discussion; two hours; outside study, six hours. Requisites: course M16 or Computer Science M51A, Computer Science 33. Recommended: course M115B or Computer Science M129A. Computer Science 111. Computer system organization and design, implementation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Roychowdhury (F,Sw,Sp)

M116D. Digital Design Project Laboratory. (4) (Same as Computer Science M152B.) Laboratory, four hours; discussion; two hours; outside study, six hours. Requisites: course M116 or Computer Science M151B. 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. He (F,Sw,Sp)

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

83
M171. Computer Networks: Physical Layer. (6) (Same as Computer Science M117.) Lecture, four hours; discussion, four hours; outside study, 10 hours. Not open to students with credit for course M171L. Introduction to fundamental data communication concepts underlying and supporting modern networks, with focus on physical and media access layers of the TCP/IP stack. Systemovable 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. Outcomes include microfabrication technologies and microelectromechanical systems (MEMS), Methods of micromachining and how these methods can be used to produce variety of MEMS, including microsensors, and microactuators. Students design micromachination processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250L. Letter grading. Mr. Judy (F)

CM150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Formerly numbered M150L.) (Same as Biological Engineering CM150L and Mechanical and Aerospace Engineering CM180L.) Lecture, one hour; laboratory, four hours; outside study, seven hours. Corequisite: course CM200L. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) fabrication. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microsensors, and microactuators. Students design micromachination processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250L. Letter grading. Mr. Judy (F)

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

162A. Wireless Communication Links and Antennas. (4) Lecture, three hours; discussion, one hour; outside study, seven hours. Requisite: course 161. Basic properties of transmitting antennas and antenna arrays. Array synthesis. Adaptive arrays. Fris transmission formula, radar equations. Cell-site and mobile antennas, bandwidth budget. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Rahmat-Samii (Sp)

163A. Introductory Microwave Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 161. Transmission lines description of waveguides, impedances and antenna arrays. Array synthesis. Adaptive arrays. Fris transmission formula, radar equations. Cell-site and mobile antennas, bandwidth budget. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Itoh (W)

163B. Microwave and Millimeter Wave Active Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 121B. MESFET, HEMT, HBT, IMPATT, Gunn, small signal models, noise model, large signal model, loadpull method, parameter extraction, and device grading. Mr. Chang, Mr. Pan (not offered 2006-07)

163C. Active Microwave Circuits. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 115A, 161. Theory and design of microwave transistor amplifiers and oscillators; stability, noise, distortion. Letter grading. Mr. Itoh (F)
174. Fourier Optics. (4) Lecture; three hours; discussion, one hour; outside study, eight hours. Requisites: courses 102, 161. Two-dimensional linear systems and Fourier transforms. Foundation of diffraction theory. Analysis of optical imaging systems. Spatial filtering and optical information processing. Wavefront reconstruction and holography. Letter grading. Mr. Joshi, Mr. Stafsudd (F, Sp).

175. Fourier Optics. (4) Lecture; three hours; discussion, one hour; outside study, eight hours. Requisites: courses 102, 161. Two-dimensional linear systems and Fourier transforms. Foundation of diffraction theory. Analysis of optical imaging systems. Spatial filtering and optical information processing. Wavefront reconstruction and holography. Letter grading. Mr. Joshi, Mr. Stafsudd (F, Sp).

176. Lasers in Biomedical Applications. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 101. Study of different types of laser systems and their operation. Examination of their roles in current and projected biomedical applications. Specific capabilities of laser radiation to be related to each example. Letter grading. Mr. Feffermann.

180D. Systems Design. (4) (Formerly numbered 190D.) Lecture, two hours; laboratory, two hours; outside study, eight hours. Limited to senior Electrical Engineering majors. Advanced systems design integrating communications, control, and signal processing subsystems. Different project to be assigned yearly in which student teams create high-performance designs that manage trade-offs among subsystems. Letter grading. Mr. Kaiser, Mr. Pottie (F, Sp).

181L. Introduction to Plasma Electronics. (4) (Same as Physics M114.) Lecture, three hours. Requisite: course 101 or Physics 110A. 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.

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

194. Research Group Seminars: Electrical Engineering. (2 to 4) Seminar, four hours; discussion, one hour; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Letter grading. (W, Sp).

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

Graduate Courses

201A. VLSI Architectures and Design Methodologies. (4) Lecture; four hours; outside study, eight hours. Requisite: course M216A or Computer Science M258A. In-depth study of VLSI architectures and VLSI design methodologies for variety of applications in signal processing, communications, networking, embedded systems, etc. VLSI design 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. Versaw, Mr. Wu (Sp).

201C. Modeling of VLSI Circuits and Systems. (4) Lecture; four hours. Requisite: course 115C. Detailed study of VLSI circuit and system models considering performance, signal integrity, power and thermal effects, reliability, and manufacturability. Discussion of principles of modeling and optimization codevelopment. Letter grading. Mr. He (Sp).

Mr. Levin (F)


Mr. Levin (F)


Mr. Kaiser (W)


Mr. Sayed (Sp)


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 (F)


Mr. Willson (F)

212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems; polyphase representation; multistage implementations; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; paralyzable filter banks; wavelet transform and its relation to multirate filtering; and noise shaping. Letter grading.

Mr. Willson (W)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 212A, 216A. Digital filter design. Time-decision (DWT) and H_oo based digital signal processing circuits; integrated circuit modules for digital signal processing; programmable signal processors; CAD tools and cell libraries for application-specific integrated circuits. Letter grading.

Mr. Jain (Sp)

214A. Digital Speech Processing. (4) (Same as Biomedical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 113. Theory and applications of digital processing of speech signals. Mathematical models of human speech production and perception. Vocal tract impedance synthesis. Techniques include linear prediction, filter-bank models, and homomorphic filtering. Applications to speech coding and automatic speech recognition, and hearing aids. Letter grading.

Ms. Alwan (W)

214B. Advanced Topics in Speech Processing. (4) Lecture, three hours; computer assignments, two hours; outside study, seven hours. Requisite: course 214A. Study of 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 (W, even years)

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

Mr. Fetterman, Mr. Pan (Sp)

215B. Advanced Digital Integrated Circuits. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 115C, 216A. Analysis and comparison of standard bipolar and MOS (CMOS, bipolar, Bi-CMOS, GaAs) IC's. MSI digital circuits (flipflops, registers, counters, PLAs). VLSI memories (ROM, RAM, CCD, bubble memories, EPROM, EEPROM) and VLSI systems. Letter grading.

Ms. Verbauwhede (W or Sp)

215C. Analysis and Design of RF Circuits and Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 215A. Principles of RF circuit and system design, with emphasis on monolithic implementation in VLSI technologies. Basic concepts, communications background, transceiver architecture, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading.

Mr. Razavi (W)


Mr. Abidi (Sp)

215E. Signaling and Synchronization. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 215A, 216A. Analysis and design of circuits for synchronization and communication for VLSI systems. Use of both digital and analog design techniques to improve data rate of electronics between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading.

Mr. C.K. Yang (Sp)

216A. Design of VLSI Circuits and Systems. (4) (Same as Computer Science M258B.) Lecture, four hours; laboratory, four hours. Requisite: course 216A. VLSI design and application in circuit systems. In-depth study of VLSI memories and VLSI design tools. In Progress (M216B) and S/U or letter (M216C) grading.

Mr. Jain (Sp)

217A. Biomedical Imaging. (4) (Same as Biomedical Engineering M217A.) Lecture, four hours; laboratory, two hours; outside study, seven hours. Requisite: course 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, positron-emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, image reconstruction algorithms, system configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. Letter grading.

Mr. Grundfest (Sp)

219A. Special Topics in Circuits and Signal Processing. (4) Lecture, three hours; outside study; nine hours. Advanced treatment of topics selected from research areas in circuit theory, integrated circuits, or signal processing. Letter grading.

Mr. Villasenor, Mr. Yang (Sp)

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

Mr. K.L. Wang, Mr. Woo (W)

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

Mr. Vasanthan, Mr. Woo (W)

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

Mr. Fetterman, Mr. Pan (Sp)


Mr. Chang, Mr. Moo (Sp, odd years)


Mr. Fetterman, Mr. Pan (F)
224. Solid-State Electronics II. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Techniques to solve Boltzmann transport equation, microscopic scattering mechanisms in solid-state devices, high field transport properties in semiconductors, Monte Carlo method in transport. Optical properties. Letter grading. Mr. Parry Staatsfud (Sp, alternate years)

225. Physics of Semiconductor Nanostructures and Devices. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods for calculating electronic and optical properties of semiconductor structures. Quantum size effects and low-dimensional systems. Application to semiconductor nanometer scale devices, including negative resistance diodes, transistors, and detectors. Letter grading. 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, outside study, by arrangement. Preparation: successful completion of Ph.D. major field examination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electromagnetic circuits and applications (Section 2). Students report on a tutorial topic and on a research topic in their dissertation area. May be repeated for credit. S/U grading. (F,W,Sp)

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

230B. Digital Communication Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 132A, 230A. Basic concepts of digital communication systems; representation of bandpass waveforms; signal space analysis and optimum receiver performance; space-time coding; modulation methods; synchronization and adaptive equalization; applications to modern communication systems. Letter grading. Mr. Fitz (W)


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

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

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Fundamentals of error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading. Mr. Wesel (Sp)

232A. Stochastic Modeling with Applications to Telecommunication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Introduction to stochastic processes as applied to study of telecommunication systems and traffic engineering. Renewal theory; discrete-time Markov chains; continuous-time Markov jump processes. Applications to traffic and queueing analysis of basic telecommunication system models. Letter grading. Mr. Fitz, Mr. Wesel (F)

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

232C. Telecommunication Architecture and Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Analysis and design of integrated-service telecommunications, networks and multiple-access procedures. Stochastic analysis of priority-based queuing system models. Queueing networks; network protocol architectures; error control; routing, flow, and access control; connections 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 schemes, 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 synthesis problems with graph theoretic methods: in capaci- ty constrained (or cost constrained) networks. Devel- opment of tools of network flow theory using graph theoretic methods; application to communication, transportation, and computer networks. Letter grading. Mr. Roychowdhury, Mr. Rubin (W,Sp)

233A. Wireless Communication Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Discussion of theory of physical layer and medium access design for wireless communica- tions. Topics include wireless signal propagation and channel modeling, information theoretic studies of wireless models, performance analysis, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access schemes. Letter grading. Mr. Fitz (Sp)

233B. Wireless Communications Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 233B. Various aspects of physical layer and medium access design for wireless communications systems. Topics include wireless signal propagation and channel modeling, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access schemes, transceiver design and effects of nonideal components, hardware partitioning issues. Case study highlights system level trade-offs. Letter grading. Mr. Daneshrad (Sp)

236A. Linear Programming. (4) Lecture, four hours; outside study, eight hours. Requisite: Mathematics 115A or equivalent knowledge of linear algebra. Basic graduate course in linear optimization. Geometry of linear programming. Duality. Simplex method. Inter- rior-point methods. Decomposition and large-scale linear programming. Quadratic programming and complementary pivot theory. Engineering applications. Introduction to integer linear programming and computational complexity theory. Letter grading. Mr. Jacobsen, Mr. Vandenbergh (Jr)


236C. Optimization Methods for Large-Scale Sys- tems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 236B. Theory and computa- tional procedures for large-scale optimi- zation problems: cutting-plane methods, column generation, decomposition algorithms. Techniques for nonsmooth and continuous optimization: bundle methods, reverse convex programming, bilinear and biconvex optimization, genetic algorithms, simulated annealing. Introduction to combinatorial optimization. Letter grading. Mr. Roychowdhury (Sp)

237. Dynamic Programming. (4) (Formerly numbered 237.) (Same as Mechanical and Aerospace Engineering M276). Lecture, four hours; outside study, eight hours. Recommended requisite: course 237B or 236B or 236A. Introduction to mathematical analysis of sequential decision processes. Finite hori- zon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solu- tion: Examples from inventory theory, finite net- work control and estimation, Markov decision process- es, combinatorial optimization, communications. Let- ter grading. Mr. Jacobsen, Mr. Vandenbergh (Sp)

238. Multimedia Communications and Process- ing. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131A. Recommended: courses 114D, 231A. Key concepts, principles, and algorithms of real-time multimedia communica- tions and processing and heterogeneous Internet transport and wireless channels. Due to flexible and low-cost infrastructure, new networks and communication channels enable variety of delay-sensitive multimedia transmission applications and provide varying re- sources with limited support for quality of service re- quired by delay-sensitive, bandwidth-intensive, and loss-tolerant multimedia applications. Variability of re- sources does not significantly impact delay-insensi- tive applications (e.g., file transfers) but has conse- quences for multimedia applications and leads to new challenges. Concepts, theories, and solutions that have dominated information theory, communica- tions, and signal processing areas are not entirely suited for time-varying channel characteristics, adap- tive and delay-sensitive multimedia applications, and multimedia transmission environments. Letter grading. Ms. Van der Schaar (Sp)

239A. Topics in Communication. (4) Lecture, four hours; outside study, eight hours. Topics in one or more special areas of telecommunication 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.

Mr. Liu (Sp, alternate years)


Mr. Liu, Mr. Yablonovitch (W, alternate years)

274. Fiber Optic System Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 173DL and/or 174. Top-down introduction to physical layer design in fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-aided design. Architectural-level design of fiber optic transceiver circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading.

Mr. Jai (Sp)

279S. Special Topics in Quantum Electronics. (4) Lecture, four hours; outside study, eight hours. Current research topics in quantum electronics, lasers, nonlinear optics, optoelectronics, ultrastable phenomena, fiber optics, and lightwave technology. May be repeated for credit. Letter grading.

Mr. Joshi, Mr. Wu (F,W,Sp)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and streaming instabilities. Application to experiments in fully and partially ionized gases. Letter grading. Mr. Joshi, Mr. Mori (W)


Mr. Chen, Mr. Joshi (Sp)


Mr. Chen, Mr. Joshi (W)

295. Technical Writing for Electrical Engineers. (2) Lecture, two hours. Requisites: for electrical engineering Ph.D. students. Opportunity for students to improve technical writing skills by revising conference, technical, and journal papers and practicing writing about their work for undergraduate audience (potential students), engineers outside their specific fields, and nonscientists (colleagues with less expertise in field and policymakers). Students write in variety of genres, all related to their professional development as electrical engineers. Emphasis on writing as vital way to communicate precise technical and professional information in distinct contexts, directly resulting in specific outcomes. S/U grading.

Ms. Alwan (W)

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

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate electrical engineering students. Seminars may be organized in advanced technical areas. If appropriate, field trips may be arranged. May be repeated with topic change. S/U or letter grading.

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


Mr. Jacobson (Sp)

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

597A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate electrical engineering students. Preparation: apprenticeship personal employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance and supervision of regular faculty member responsible for curriculum and instruction at the University. May be repeated for credit. S/U grading.

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

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate electrical engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

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

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

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

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

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

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

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

**Department Mission**

The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

**Undergraduate Program Objectives**

The Materials Engineering major at UCLA prepares undergraduate students for employment or advanced studies with industry, the national laboratories, state and federal agencies, and academia. To meet the needs of these constituencies, the objectives of the undergraduate program are to produce graduates who (1) possess a solid foundation in materials science and engineering, with emphasis on the fundamental scientific and engineering principles that govern the microstructure, properties, processing, and performance of all classes of engineering materials, (2) understand materials processes and the application of general natural science and engineering principles to the analysis and design of materials systems of current and/or future importance to society, (3) have strong skills in independent learning, analysis, and problem solving, with special emphasis on design of engineering materials and processes, communication, and an ability to work in teams, and (4) understand and are aware of the broad issues relevant to materials, including professional and ethical responsibilities, impact of materials engineering on society and environment, contemporary issues, and need for lifelong learning.

**Undergraduate Study**

**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.

**Materials Engineering Option**

**Preparation for the Major**

**Required:** Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1).

**The Major**

**Required:** Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Civil and Environmental Engineering 101 (or Mechanical and Aerospace Engineering 101), 108, Electrical Engineering 100, Materials Science and Engineering 104, 110, 110L, 120, 130, 131, 131L, 132, 140, 143A, 150, 160, Mechanical and Aerospace Engineering 181A or 182A; two laboratory courses (4 units) from Materials Science and Engineering 121L, 141L, 143L, 161L; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses.

![The X-ray Photoemission Spectrometer and UV Photoemission Spectrometer is equipped with a sample preparation chamber. The first of its kind at UCLA, it was awarded to Professor Yang Yang’s laboratory through an Air Force grant.](image-url)
courses (12 units) from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical Engineering 2, 123A, 123B, 124, Materials Science and Engineering 111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C, plus at least one elective course (4 units) from Chemistry and Biochemistry 30A, 30AL, Electrical Engineering 131A, Materials Science and Engineering 170, 171, Mathematics 170A, or Statistics 100A.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Electronic Materials Option

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Electrical Engineering 10; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C (or Electrical Engineering 1).

The Major

Required: Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Electrical Engineering 101, 121B, Materials Science and Engineering 104, 110, 110L, 120 (or Electrical Engineering 2), 121, 121L, 122, 130, 131, 131L, 140, Mechanical and Aerospace Engineering 101, and 181A or 182A; four courses (16 units) from Electrical Engineering 123A, 123B, Materials Science and Engineering 132, 150, 160; 4 laboratory units from Electrical Engineering 172L, Materials Science and Engineering 141L, 161L, 199; three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and one major field elective course (4 units) from Electrical Engineering 110, 124, 131A, 172, Materials Science and Engineering 111, 143A, 162.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 21 or http://www.registrar.ucla.edu/ge/GE-ENGRNew 06-07.pdf.

Graduate Study

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

The following introductory information is based on the 2006-07 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the “Publications” link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.

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

Materials Science and Engineering M.S.

Areas of Study

There are three main areas in the M.S. program: ceramics and ceramic processing, electronic and optical materials, and structural materials. Students may specialize in any one of the three areas, although most students are more interested in a broader education and select a variety of courses. Basically, students select courses that serve their interests best in regard to thesis research and job prospects.

Course Requirements

Thesis Plan. Nine courses are required, of which six must be graduate courses. The courses are to be selected from the following lists, although suitable substitutions can be made from other engineering disciplines or from chemistry and physics with the approval of the departmental graduate adviser. Two of the six graduate courses may be Materials Science and Engineering 598 (thesis research).

Comprehensive Examination Plan. Nine courses are required, six of which must be graduate courses, selected from the following lists with the same provisions listed under the thesis plan. The remaining three courses in the total course requirement may be upper division courses.

Comprehensive Examination 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).

Electronic and optical materials: Materials Science and Engineering 111, 121, 122, 143A, 151, 161, 162, 200, 201, 243A, 243C, 244, 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 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Thesis Plan

In addition to fulfilling the course requirements, under the thesis plan students are required to write a thesis on a research topic in materials science and engineering supervised by the thesis adviser. An M.S. thesis committee composed of three departmental faculty members, including the thesis chair, reviews and approves the thesis.

Comprehensive Examination Plan

Consult the graduate adviser for details. If the comprehensive examination is failed, students may be reexamined once with the consent of the graduate adviser.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines

Ceramics and ceramic processing, electronic and optical materials, and structural materials.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed to satisfy the written preliminary examination requirement. In this case, a grade-point average of at least 3.33 in all courses is required, with a grade of B— or better in each course. The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of knowl-
edge contained in nine courses, at least six of which must be graduate courses, plus the current literature in the area of specialization. Materials Science and Engineering 599 may not be applied toward the nine-course total. The major fields named above are described in a Ph.D. major field syllabus, each of which can be obtained in the department office.

The minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor field is selected to support the major field and is usually a subset of the major field.

For information on completing the Engineer degree, see Schoolwide Programs, Courses, and Faculty.

Written and Oral Qualifying Examinations

During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination which encompasses the body of knowledge in materials science equivalent to that expected of a bachelor's degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice.

After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student's preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are “inside” members and must hold appointments at UCLA in the student's major department in HSSEAS. The “outside” member must be a UCLA faculty member outside the student's major department. Faculty members holding joint appointments with the Materials Science and Engineering Department are considered “inside” members.

Fields of Study

Ceramics and Ceramic Processing

The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melting, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials

The electronic and optical materials field provides an area of study in the science and technology of electronic materials which includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications which include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities

Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Electron Microscopy Laboratories with a scanning transmission electron microscope (100 keV), a field emission transmission electron microscope (200 keV), and a scanning electron microscope, all equipped with a full quantitative analyzer, a stereo microscope, microcameras, and metallurgical microscopes
- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Nano-Materials Laboratory
- Nondestructive Testing Laboratory
- Organic Electronic Materials Processing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonders
- X-Ray Diffraction Laboratory
- X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors

Russel E. Cailfisch, Ph.D. (New York U., 1978) Theory and numerical simulation for materials physics, epitaxial growth, nanoscale systems, semiconductor device properties and design in applications to quantum well devices, quantum dots, nanocrystals and quantum computing

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

Nasr M. Ghoniem, Ph.D. (Wisconsin, 1977) Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

Mark S. Goorsky, Ph.D. (MIT, 1989) Electronic materials processing, strain relaxation in epitaxial semiconductors and device structures, high-resolution X-ray diffraction of semiconductors, ceramics, and high-strength alloys

Vijay Gupta, Ph.D. (MIT, 1989) Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

H. Thomas Hahn, Ph.D. (Pennsylvania State, 1971) Nanocomposites, multifunctional composites, nanomechanics, rapid prototyping, information systems

Richard B. Kaner, Ph.D. (Pennsylvania, 1984) Rapid synthesis of high-temperature materials, conducting polymers as separation membranes for enantiomers, synthesis of carbon nanoscrolls and composites
Qibing Pei, Ph.D. (Chinese Academy of Sciences, 1990)  
Electroactive polymers through molecular design and nanotechnology for electronic devices and artificial muscles

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

Fred Wudl, Ph.D. (UCLA, 1967)  
Organic materials synthesis, organic electronic devices, including field-effect transistors, light-emitting devices, organic metals and superconductors; Fullerene chemistry applied to these areas

Yu-Hong Xie, Ph.D. (UCLA, 1986)  
Hetero-epitaxial growth of semiconductor thin films: strained Si, self-assembled quantum dots, and other epitaxial nano-structures; Si substrate impedance engineering for mixed-signal integrated circuit technologies

Jenn-Ming Yang, Ph.D. (Delaware, 1986)  
Mechanical behavior of polymer, metal, and ceramic matrix composites, electronics packaging

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

Alan J. Ardell, Ph.D. (Stanford, 1964)  
Film formation, mechanical testing of structural materials, acoustic emission, dislocations and strengthening mechanisms, microstructural effects, and ultrasound

William Klement, Jr., Ph.D. (Cal Tech, 1962)  
Phase transformations in solids, high-pressure effects on solids

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

Marek A. Przystupa, Ph.D. (Michigan Tech, 1980)  
Mechanical behavior of solids

Benjamin Wu, Ph.D. (MIT, 1997)  
Processing, characterization, and controlled delivery of biological molecules of bioreducible polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Kanji Ono, Ph.D. (Northwestern, 1964)  
Chemical and physical properties of non-metallic archaeological materials; alteration processes in archaeological vitreous materials and pigments

Phase transformations in solids, high-pressure effects on solids

William Klement, Jr., Ph.D. (Cal Tech, 1962)  
Phase transformations in solids, high-pressure effects on solids

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

Marek A. Przystupa, Ph.D. (Michigan Tech, 1980)  
Mechanical behavior of solids

Lower Division Courses

10. Freshman Seminar: New Materials. (1) (Formerly numbered 88)  
Seminar, one hour; outside study, two hours. Preparation: high school chemistry and physics. Not open to students with credit for course 104 or former course 14. Introduction to basic concepts of materials science and new materials vital to advanced technology. Microstructural analysis and various material properties discussed in conjunction with applications as biomedical sensors, pollution control, and microelectronics. Letter grading.

11. Introduction to Materials Characterization A Laboratory. (2)  
Laboratory, four hours, including electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading.

110L. Introduction to Materials Characterization B Laboratory. (2)  
Laboratory, four hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy: emissive and reflective modes; chemical analysis; electron optics of both instruments. Letter grading.

120. Physics of Materials. (4)  
Lecture, four hours; outside study, eight hours. Requisites: courses 104, 110 (or Chemistry 115A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading.

121. Materials Science of Semiconductors. (4)  
Lecture, four hours; outside study, eight hours. Requisites: courses 104, 110 (or Chemistry 115A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading.

121L. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

123. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

124. Physics of Materials. (4)  
Lecture, four hours; outside study, eight hours. Requisites: courses 104, 110 (or Chemistry 115A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading.

125. Materials Science of Semiconductors. (4)  
Lecture, four hours; outside study, eight hours. Requisites: courses 104, 110 (or Chemistry 115A). Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading.

Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

127. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

129. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

130. Principles of Electronic Materials Processing. (4)  
Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

131. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

133. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

135. Materials Science of Semiconductors Laboratory. (2)  
Laboratory, two hours; outside study, three hours. Requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Lecture, four hours; outside study, eight hours. Requisites: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.
123. Electronic Packaging and Interconnection. (2) Lecture, two hours; outside study, six hours. Various electronic packaging methods and interconnect technology, 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 104, and Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A. Summary of thermodynamic laws, equilibrium criteria, solution thermodynamics, mass-action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Goorsky (F)

131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermediate phases, gas-solid reactions, design of oxidation-resistant alloys, recrystallization, and grain growth. Letter grading. Mr. Tu (W)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, 12 hours. Design of heat-treating cycles and performing experiments to study interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. Mr. Tu (W)

132. Structure and Properties of Metallic Alloys. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Physical metallurgy of steels, lightweight alloys (Al and Ti), and superalloys. Strengthening mechanisms, microstructural control methods for strength and toughness improvement. Grain boundary segregation. Letter grading. Mr. Ono (Sp)

140. Materials Selection and Engineering Design. (4) (Formerly numbered 190.) Lecture, four hours; outside study, eight hours. Requisites: courses 132, 150, 160. Explicit guidance among myriad material properties available for design in engineering. Properties and applications of steels, nonferrous alloys, polymeric, ceramic, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading. Mr. Przyzmut (Sp)

141L. Computer Methods and Instrumentation in Materials Science. (2) (Formerly numbered 191L.) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to junior or senior Materials Science and Engineering majors. Interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading. Mr. Przyzmut (Sp)

143A. Mechanical Behavior of Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Mechanical and Aerospace Engineering 101. Plastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocations, fracture, microstructural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. Przyzmut (W)

143L. Mechanical Behavior Laboratory. (2) Laboratory, four hours. Requisites: courses 99L, 143A (may be taken concurrently). Preparation: knowledge of characterizing mechanical behavior of various materials; elastic and plastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. Ono (W)

150. Introduction to Polymers. (4) Lecture, three hours; laboratory, one hour. Preparation: Polymers and Polymerization Mechanisms, molecular weight and distribution, chemical structure and bonding, structure crystallinity, and morphology and their effects on physical properties. Glassy polymers, elastomers, and thermoplastic adhesives. Fiber forming polymers, polymer processing technology, plasticization. Letter grading. Mr. J-M. Yang (W)

151. Structure and Properties of Composite Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: at least two courses from 132, 143A, 150, 160. Requisite: course 104. Relationship between structure and mechanical properties of composite materials with fiber and particulate reinforcement. Properties of fiber, matrix, and interfaces. Selection of macrostructures and material systems. Letter grading. Mr. Ono (Sp)

160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 104, 130. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading. Mr. Dunn (F)

161. Processing of Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour. Requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting. Microstructural properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading. Mr. Dunn (W, even years)


162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Electrical Engineering 1 (or Physics 1C), Utilization of ceramics in microelectronics; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferroelectric ceramics and electro-optic devices; optical wave guide applications and designs. Letter grading. Mr. Dunn (W, odd years)

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

171. Engaging Elements of Communication: Writing for Technical Community. (2) (Formerly numbered 197.) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive technical writing skills on subjects specific to field of materials science and engineering. Students write review term paper in selected subject field of materials science and engineering from given set of journal publications. In-class instruction leads students through several critical steps, including brainstorming, choosing title, coming up with outline, concise writing of abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and grammar. Letter grading. Mr. Xie (F,W,Sp)

CM180. Introduction to Biomaterials. (4) (Same as Biomedical Engineering CM180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 104, 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 and body interactions, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading. Mr. Wu (Sp)

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

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

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

Graduate Courses

200. Principles of Materials Science I. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Lattice dynamics and thermal properties of solids; classical and quantum-free-electron theory; electrons in a periodic potential, transport in semiconductors, dielectric and magnetic properties of solids. Letter grading. Mr. Dunn (F)


221. Science of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Study of major physical and chemical principles affecting properties and performance of semiconductor materials. Topics include bonding, carrier statistics, band-gap engineering, optical and transport properties, novel materials systems, and characterization. Letter grading. Mr. Goorsky (Sp)

222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 130, 131. Thermodynamics and kinetics that affect semiconductor growth and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), heteroepitaxy, implantation, oxidation. Letter grading. Mr. Goorsky (W)

223. Materials Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131. Fabrication, structure, and property correlations of thin films used in microelectronics for data and information processing. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading. Mr. Tu
224. Deposition Technologies and Their Applications. (4) Lecture, three hours; outside study, nine hours. Designed for graduate engineering students. Deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-assisted vapor deposition processes, plasma spray deposition. Applications in semiconductor, chemical, optical, mechanical, and metallurgical industries. Letter grading. Mr. Xie


226. Si-CMOS Technology: Selected Topics in Materials Science. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Recommended preparation: Electrical Engineering 221B. Requires: courses 130, 131, 200, 221, 222. Selected topics in materials science from modern Si-CMOS technology, including technological challenges in high k/metal gate stacks, strained Si FETs, SOI and three-dimensional FETs, source/drain engineering including transient-enhanced diffusion, nonvolatile memory, and metallization for ohmic contacts. Letter grading. Mr. Xie

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Requires: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and fracture. Fracture mechanics, dislocation models, fatigue, fracture in reactive environments, alloy development, fracture-safe design. Letter grading. Mr. Ono (W, even years)

243C. Dislocation and Strengthening Mechanisms in Solids. (4) Lecture, four hours; outside study, eight hours. Requires: course 143A or Mechanical and Aerospace Engineering 156B. Elastic and plastic behavior of crystals, geometry, mechanics, and 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. Requires: course 111. Essential features of electron microscopy, geometry of electron diffraction, kinematical and dynamical theories of electron diffraction, including anomalous absorption, applications of theory to defects in crystals. Moiré fringes, direct lattice resolutions, Lorentz microscopy, laboratory applications of contrast theory. Letter grading. Mr. Ardell (Sp, even years)

245C. Diffraction Methods in Science of Materials. (4) Lecture, four hours; outside study, eight hours. Requires: course 110. Theory of diffraction of 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)

246B. Structure and Properties of Glass. (4) Lecture, four hours; outside study, eight hours. Requires: course 160. Structure of amorphous solids and glasses. Conditions of glass formation and theories of glass structure. Mechanical, electrical, and optical properties of glass and relationship to structure. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; outside study, eight hours. Requires: course 160. Principles governing electronic properties of ceramic single crystals and glasses and effects of processing and microstructure on these properties. Electronic conduction, ferroelectricity, and photochromism. Magnetic ceramics. Infrared, ultraviolet, and photoelectron transmission. Unique application of ceramics. Letter grading. Mr. Dunn (Sp, even years)


251. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic molecules, synthetic polymers, and biomolecules and biomaterials. Essential description and discussion of structure-property relationships, spectroscopic and experimental techniques, and preparation methods for various soft materials. Letter grading. Mr. Pei

252. Organic Polymer Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Prepa- ration: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers; heavily doped, highly conducting polymers; applications as processable metals and in various electrical, optical, and electrochemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Intro- duction to emerging field of organic electronics. Letter grading. Mr. Pei (F, odd years)

CM280. Introduction to Biomaterials. (4) (Same as Biomedical Engineering CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requires: course 104, or Chemistry 28A, 28B, and 28L. 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. Normally offered in advanced technical fields. Il appropriate, field trips may be arranged. May be repeated with topic change. Letter grading.

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

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


599. Research for and Preparation of Ph.D. Dis- sertation. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering stu- dents. Usually taken after students have been ad- vanced to candidacy. S/U grading.
Mechanical and Aerospace Engineering

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Gregory P. Carman, Ph.D.
Albert Carnesale, Ph.D.
Ivan Catton, Ph.D.
Yong Chen, Ph.D.
Vijay K. Dhir, Ph.D., Dean
Rajit Gadh, Ph.D.
Nass M. Ghoniem, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
H. Thomas Hahn, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
Chi-Hsien Ho, Ph.D. (Ben Rich Lockheed Martin Professor of Aeronautics)
Ann R. Karagozian, Ph.D.
Chang-Jin (C-J) Kim, Ph.D.
J. John Kim, Ph.D. (Rockwell International Professor of Engineering)
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Kuo-Nan Liou, Ph.D.
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Robert T. M’Closkey, Ph.D.
Anthony F. Mills, Ph.D.
Jeff S. Shamma, Ph.D.
Owen I. Smith, Ph.D.
Jason Speyer, Ph.D.
Tsu-Chin Tsao, Ph.D.
Daniel C.H. Yang, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti
Andrew F. Charwat, Ph.D.
Peretz P. Friedman, Sc.D.
Walter C. Hurty, M.S.
Robert E. Kelly, Sc.D.
Cornelius T. Leondes, Ph.D.
Michel A. Melkanoff, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkewitz, Ph.D.
Philip F. O’Brien, M.S.
David Okrent, Ph.D.
Russell R. O’Neill, Ph.D., Dean Emeritus
Lucien A. Schmit, Jr., M.S.
Chauncey Stann, Ph.D., Dean Emeritus
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.

Assistant Professors
Pei-Yu Chiou, Ph.D.
Jeff D. Eldredge, Ph.D.
Emilio Frazzoli, Ph.D.
Yongho Sungtaek Ju, Ph.D.
H. Piouz Kavehpour, Ph.D.
William S. Klug, Ph.D.
Laurent Pilol, Ph.D.

Senior Lecturer
Alexander Samson, Ph.D., Emeritus

Lecturers
Ravnesh Amar, Ph.D.
C.H. Chang, M.S., Emeritus
Amiya K. Chatterjee, Ph.D.
Wilbur J. Marner, Ph.D.
Rudolf X. Meyer, Dr. Engr., Emeritus

Adjunct Professors
Leslie M. Lackman, Ph.D.
Joseph Miller, Ph.D.
Neil B. Morley, Ph.D.
Raymond Viskanta, Ph.D.
Xiang Zhang, Ph.D.

Scope 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.

Because of the scope of the department, faculty research and teaching cover a wide range of technical disciplines. Research in thermal engineering emphasizes basic heat and mass transfer processes as well as thermal hydraulics. Topics in the area of design, dynamics, and control include robotics, mechanism design, control and guidance of aircraft and spacecraft, aeromechanics, and dynamics and control of large space structures. Studies in structural mechanics range from fracture mechanics and wave propagation, structural dynamics and aeroelasticity of helicopters and jet engine blades, computational transonic aeroelasticity to structural optimization and synthesis, and mechanics of composite structures. In the area of fluid mechanics and acoustics, investigations are under way on combustion, flow instabilities, turbulence and thermal convection, aeroacoustics, and unsteady aerodynamics of turbomachines, helicopter rotors, and fixed-wing aircraft. Other areas of research include applied plasma physics, surface modification by plasma, fusion reactor design, experimental tokamak confinement physics; light water reactor safety; reliability and risk assessment methodology; and nuclear materials. The department also has research activity in computer-aided design and manufacturing.

At the undergraduate level, the department offers accredited programs leading to B.S.

degrees in Aerospace Engineering and in Mechanical Engineering. The former includes opportunity to emphasize propulsion, aerodynamics, design, dynamics and control, or structures and space technology, while the latter includes opportunity to emphasize design and manufacturing, dynamics and control, or fluids and thermal engineering.

At the graduate level, the department offers programs leading to M.S. and Ph.D. degrees in Mechanical Engineering and in Aerospace Engineering. An M.S. in Manufacturing Engineering is also offered.

Department Mission

The mission of the Mechanical and Aerospace Engineering Department is to educate the nation’s future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological innovation while fostering academic excellence and scholarly learning in a collegial environment.

Undergraduate Program Objectives

In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: (1) to teach students how to apply their rigorous undergraduate education to creatively solve technical problems facing society and (2) to prepare them for successful and productive careers or graduate studies in mechanical or aerospace or other engineering fields and/or further studies in other fields such as medicine, business, and law.

Aerospace Engineering B.S.

The ABET-accredited aerospace engineering program is concerned with the design and construction of various types of fixed-wing and rotary-wing (helicopters) aircraft used for air transportation and national defense. It is also concerned with the design and construction of spacecraft, the exploration and utilization of space, and related technological fields.

Aerospace engineering is characterized by a very high level of technology. The aerospace engineer is likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts. Meeting these demands requires the imaginative use of
many disciplines, including fluid mechanics and aerodynamics, structural mechanics, materials and aeroelasticity, dynamics, control and guidance, propulsion, and energy conversion.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 107L, 150A, 150B, 150P, 154A, 154B, 154S, 155 or 161A or 169A, 157A, 157S, 166A, 171A, 182A, two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104 – if these courses are taken as part of the breadth requirement, an extra elective from within the department may be substituted here); three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131AL, 132A, 133A, 133AL, 134, CM140, 150A, 150B, 150C, 150P, 150R, 153A, 155, 157A, 161A, 161B, 162C, 163A, 166C, 168, 171B, 172, 174, CM180, CM180L, 181A, 182B, 182C, 184, 185.

For information on University and general education requirements, see Requirements for UCLA Graduate Programs, page 24.

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

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

The following introductory information is based on the 2006-07 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.

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.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 94; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Electrical Engineering 110L, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 107L, 131A or 133A, 156A, 157, 162A, 162B, 162M, 171A, 182A, 183; two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104 – if these courses are taken as part of the breadth requirement, an extra elective from within the department may be substituted here); three breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131AL, 132A, 133AL, 134, CM140, 150A, 150B, 150C, 150P, 150R, 153A, 155, 157A, 161A, 161B, 162C, 163A, 166C, 168, 171B, 172, 174, CM180, CM180L, 181A, 182B, 182C, 184, 185.

For information on University and general education requirements, see Requirements for UCLA Graduate Programs, page 24.

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

The following introductory information is based on the 2006-07 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 102A, 199; Civil and Environmental Engineering 106A, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 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 66A or 169A, (4) 161A or 171A.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 250C, 250D, 250F, 253B, 254A, 255B, 256F, 263B, 269D, or 271B. The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

Mechanical Engineering
Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162B or 183.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 231A, 231B, 231C, 250A, 255A, M256A, M256B, M269A, or 271A. The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

Comprehensive Examination Plan
The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination or (2) conduct a research or design project and submit a final report to the M.S. committee.

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 990 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Choices may be made from the following major areas:

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 199.

Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 163A, 168, 174, 183, 184, 185.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, CM280A, 293, 294, 295A, 295B, 296A, 296B, 297.

Additional Courses. The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design M226B, M227B, 227D; Computer Science 241A, 241B; Management 240A, 240D, 241A, 241B, 242A, 242B, 243B, 243C; Mathematics 120A, 120B.

Comprehensive Examination Plan
The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination or (2) conduct a research or design project and submit a final report to the M.S. committee.

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.

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.

Fields of Study

Dynamics

Features of the dynamics field include dynamics and control of physical systems, including spacecraft, aircraft, helicopters, industrial manipulators; analytical studies of control of large space structures; aeromechanical stability of helicopters; active control of helicopter vibrations; experimental studies of electromechanical systems; and robotics.
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 electromagneto-thermomechanical material systems. The structural mechanics field includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aeroelasticity, fluid structure interaction, computational transonic aeroelasticity, structural optimization, finite element methods and related computational techniques, mechanics of composite structures, and analysis of adaptive structures.

Systems and Control
The systems and control field deals with modeling, analysis, and control of dynamical systems. Applied mathematics is used to develop methods for stability analysis, design of optimal and robust control systems, filtering, and system identification. Courses and research programs include theoretical analysis of the performance of systems and algorithms; computational methods for simulation, optimization, control, filtering, and identification; and experimental studies involving system identification and hardware implementation of real-time control and filtering. The field covers a broad spectrum of applications areas, primarily emphasizing problems in mechanical and aerospace engineering.

Ad Hoc Major Fields
The ad hoc major fields program has sufficient flexibility that students can form academic major fields in their area of interest if the proposals are supported by several faculty members. Previous fields of study included acoustics, system risk and reliability, and engineering thermodynamics. Nuclear science and engineering, a former active major field, is available on an ad hoc basis only.

Facilities
The Mechanical and Aerospace Engineering Department has a number of experimental facilities at which both fundamental and applied research is being conducted. More information is at http://www.mae.ucla.edu.

Active Materials Laboratory
The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, magnetostriative, shape memory alloys, and fiber optic sensors. The laboratory has manufacturing facilities to fabricate magnetostriective composites and thin film shape memory alloys. Testing active material systems is performed on one of four servo-hydraulic load frames. All of the load frames are equipped with thermal chambers, solenoids, and electrical power supplies.

Autonomous Vehicle Systems Instrumentation Laboratory
The Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. The AVSIL contains a hardware-in-the-loop (HIL) simulator designed and built at UCLA that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the Inter-state Electronics Corporation GPS Satellite Constellation Simulator. The UCLA flight control software can be modified to accommodate satellite-system experiments using real-time software, GPS receivers, and inter-vehicle modem communication.

Combustion Research Laboratory
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.

Computational Fluid Dynamics Laboratory
The Computational Fluid Dynamics Laboratory has several medium-size Beowulf linux clusters for numerical simulation of transitional, turbulent, and high speed compressible flows, with and without reaction, as well as the sound that they produce. The laboratory has access to supercomputers (large clusters of parallel processors on various platforms) at NSF PACI Centers and DoD High-Performance Computing Centers.

Fluid Mechanics Research Laboratory
The Fluid Mechanics Research Laboratory includes a full line of water tunnels equipped with various advanced transducers (MEMS-based sensors and actuators, particle image anemometer, laser Doppler anemometer, hot-wire anemometers) and data acquisition systems.

Fusion Technology Center
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 (I) liquid metal magnetohydrodynamic fluid flow, (II) thick and thin liquid metals systems exposed to intense particle and heat flux loads, and (3) metallic and ceramic material thermomechanics.

Heat Transfer Laboratories
The Heat Transfer Laboratories are used for experimental research on heat transfer and thermal hydraulics. The laboratories are equipped with several flow loops, high-current power supplies, high-frequency induction power supplies, holography and hot-wire anemometry setups, and state-of-the-art data acquisition systems.

Materials Degradation Characterization Laboratory
The Materials Degradation Characterization Laboratory is used for the characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and for research on fracture mechanics and ultrasonic nondestructive evaluation.

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

Multifunctional Composites Laboratory
The Multifunctional Composites Laboratory provides equipment necessary to develop multifunctional nanocomposites and explore their applications by integrating technologies involving composites, nanomaterials, information, functional materials, biomimetics, and concurrent engineering. Some of the equipment in the laboratory includes an autoclave, a filament winder, a resin transfer molding machine, a waterjet cutting machine, a stereo lithography machine, a laminated object manufacturing machine, a coordinate measuring machine, a field emission scanning electron microscope, a scanning probe microscope, an FTIR, a rheometer, a thermal analysis system, an RCL analyzer, a microdielectric analyzer, an X-ray radiography machine, and a variety of mechanical testing machines.

Nanoscale Heat Transfer and Thermoelectrics Laboratory
The Nanoscale Heat Transfer and Thermoelectrics Laboratory (Nano-HTTL) is equipped with a scanning probe microscope (atomic force, scanning tunneling, scanning thermal, and scanning laser), infrared microscope with 4xm resolution, gas and solid-state lasers (argon, T-Sapphire, and semiconductor lasers) and optical systems, vacuum systems for low- to high-temperature property measurement (4 K-800 K), a probe station, various thin-film thermal conductivity and Seebeck coefficient measurement systems, analytical equipment, various computers for data acquisition, and an HP workstation for computational work.

Plasma and Beam Assisted Manufacturing Laboratory
The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for the purpose of processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power D.C. supplies (400kw), vacuum chambers, and large electromagnet. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

Subsonic Wind Tunnel
The 3 x 3-foot Subsonic Wind Tunnel is used for research on unsteady aerodynamics on oscillating airfoils and instruction.

Thin Films, Interfaces, Composites, Characterization Laboratory
The Thin Films, Interfaces, Composites, Characterization Laboratory consists of a Nd:YAG laser of 1 Joule capacity with three ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 Kip-capacity servohydraulic biaxial test frame, walk-in freezer, polishing and imaging equipment for microstructural characterization for measurement and control study of thin film interface strength, NDE using laser ultrasound, de-icing of structural surfaces, and characterization of composites under multiaxial stress state.

Faculty Areas of Thesis Guidance
Professors
Mohamed A. Abdou, Ph.D. (Wisconsin, 1973)
Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermomechanics, thermal hydraulics; neutronics, plasma-material interactions; blankets and high heat flux components; experiments, modeling and analysis
Oddvar O. Bendiksen, Ph.D. (UCLA, 1989)
Classical and computational aeroelasticity, structural dynamics and unsteady aerodynamics
Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelectricity models, fatigue characterization of piezoelectric ceramics, magnetostrictive composites, characterizing shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally evaluating damage in composites
Albert Carnesale, Ph.D. (North Carolina State, 1966)
Issues associated with neutral weapons and other weapons of mass destruction, energy policy; American foreign policy
Ivan Catton, Ph.D. (UCLA, 1966)
Heat transfer and fluid mechanics, transport phenomena in porous media, nucleonics heat transfer and thermal hydraulics, natural and forced convection; thermal/hydrodynamic stability, turbulence
Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, micro- and nano-scale electronic, mechanical, optical, biological, and sensing devices, circuits and systems
Vijay K. Dhir, Ph.D. (Kentucky, 1972)
Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity mass 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)
Nanocomposites, multifunctional composites, nanomechanics, rapid prototyping, information systems
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, nanoelectromechanical/microelectromechanical systems, direct handling of macromolecules, bionano technologies, DNA-based micro sensors
Ann R. Karagiozian, Ph.D. (Cal Tech, 1982)
Fluid mechanics of combustion systems with emphasis on acoustically controlled reacting flows detonation phenomena, high-speed combustion systems, and microgravity combustion
Chang-Jin (C-J) Kim, Ph.D. (UC Berkeley, 1991)
Microelectromechanical systems, microfabricating technologies, microstructures, sensors and actuators, microdevices and systems, micromanufacturing, microscale mechanics
J. John Kim, Ph.D. (Stanford, 1978)
Turbulence, numerical simulation of turbulent and transitional flows, application of control theories to flow control
Adrienne Lavine, Ph.D. (UC Berkeley, 1984)
Heat transfer: thermomechanical behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection
Kuo-Nan Liou, Ph.D. (New York U., 1970)
Radiative transfer and satellite remote sensing with application to clouds and aerosols in the earth’s atmosphere
Ajit K. Mal, Ph.D. (Calcutta U., 1964)
Mechanics of solids, fractures and failure, wave propagation, nondestructive evaluation, composite materials
Robert T. McCreary, Ph.D. (Cal Tech, 1995)
Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation
Anthony F. Mills, Ph.D. (UC Berkeley, 1965)
Convection heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers
J. S. Shamma, Ph.D. (MIT, 1988)
Feedback control theory and design with application to mechanical, aerospace, and manufacturing systems

Owen I. Smith, Ph.D. (UC Berkeley, 1977)
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition

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

Tsu-Chin Tsao, Ph.D. (UC Berkeley, 1988)
Modeling and control of dynamic systems with applications in mechanical systems, manufacturing processes, automotive systems, and energy systems, digital control, repetitive and learning control, adaptive and optimal control, mechatronics

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

Jeff S. Shamma, Ph.D. (MIT, 1988)
Feedback control theory and design with application to mechanical, aerospace, and manufacturing systems

Peter A. Monkewitz, Ph.D. (E.T.H., Federal D. Lewis Mingori, Ph.D. (Stanford, 1966)
Michel A. Melkanoff, Ph.D. (UCLA, 1955)
Cornelius T. Leondes, Ph.D. (Pennsylvania, 1968)

Xiaolin Zhong, Ph.D. (Stanford, 1991)
Computational fluid dynamics, hypersonic flow, rarefied gas dynamics, numerical simulation of transient hypersonic flow with nonequilibrium real gas effects, instability of hypersonic boundary layers

Professors Emeriti

Andrew F. Charwat, Ph.D. (UC Berkeley, 1952)
Experimental fluid mechanics, two-phase flow, ocean thermal energy conversion

Aerelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aerelastic constraints

Walter C. Hurty, M.S. (UCLA, 1948)
Dynamics of structures, including large structural systems, design and analysis of aerospace structures, stability of motion in self-excited systems

Thermal convection, thermodiffusivity, convection, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics

Cornelius T. Leondes, Ph.D. (Pennsylvania, 1964)
Applied dynamic systems control

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

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

Peter A. Monkewitz, Ph.D. (E.T.H., Federal Institute of Technology, Zurich, 1977)
Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip F. O’Brien, M.S. (UCLA, 1949)
Industrial engineering, environmental design, thermal and luminous engineering systems

David Okrent, Ph.D. (Harvard, 1951)
Fast reactors, reactor physics, nuclear reactor safety, nuclear fuel element behavior, risk-benefit studies, nuclear environmental safety, fusion reactor technology

Russell R. O’Neill, Ph.D. (UCLA, 1956)
Systems engineering, maritime transportation systems

Lucien A. Schmitz, 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

Chaucney Stark, Ph.D. (Rensselaer, 1935)
Risk-benefit analysis of technical systems, national energy policy

Richard Stern, Ph.D. (UCLA, 1964)
Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics

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

Assistant Professors

Pei-Yu Chiou, Ph.D. (UC Berkeley, 2005)
BioMEMS, biophotonics, electrokinetics, optical manipulation, optoelectronic devices

Jeff D. Eldridge, Ph.D. (Cal Tech, 2002)
Aeroacoustics, particle-based numerical methods for fluids, control of acoustically-driven instabilities, vorticity dynamics

Emilio Frazzoli, Ph.D. (MIT, 2001)
Algorithmic, geometric, and computational methods for control of autonomous and distributed aerospace systems; flight control, astrodynamics, robotics, hybrid systems

Yongho Sungtaek Ju, Ph.D. (Stanford, 1999)
Heat transfer, thermodynamics, micro- and nano-electromechanical systems (MEMS/ NEMS), magnetics, nano-bio technology

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

Computational structural and solid mechanics, finite element methods, computational biomechanics, nanomechanical systems

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

Senior Lecturer

Alexander Samson, Ph.D. (U. New South Wales, 1968), Emeritus
Electromechanical system design, mechanical design, design of mechanical energy systems

Lecturers

Raveshen Amar, Ph.D. (UCLA, 1974)
Heat transfer and thermal science

C.H. Chang, M.S. (UCLA, 1985), Emeritus
Computer-aided manufacturing and numerical control

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

Wilbur J. Minter, Ph.D. (South Carolina, 1969)
Thermal sciences, system design

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

Adjunct Professors

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

Joseph Miller, Ph.D. (UCLA, 1962)
High-energy lasers, space instruments, space propulsion, multidisciplinary project management and leadership, engineering and society

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

Raymond Viskanta, Ph.D. (Purdue, 1960)
Radiative transfer, heat transfer in combustion systems, heat transfer in manufacturing, simulation of electronic devices using Boltzmann Transport Equation

Xiang Zhang, Ph.D. (UC Berkeley, 1996)
Nano-micro fabrication and MEMS, laser microtechnology, nano-micro devices (electronic, mechanical, photonic, and biomedical), rapid prototyping and microstereolithography, design and manufacturing in nano-micro scale; semiconductor manufacturing, physics and chemistry in nano-micro devices and fabrication.

Lower Division Courses


15. Technical Communication for Engineers. (2) Lecture, two hours; outside study, four hours. Requirement: English Composition 3. Understanding writing process. Determining the purpose, prewriting, principles of organizing technical information. Eliminating unnecessary words, structuring paragraphs clearly, structuring effective sentences. Writing abstracts, introductions, and conclusions. Drafting and reviewing coherent documents. Writing collaboratively. Letter grading. Ms. Lavine (FW)

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

20. Programming with Numerical Methods Applications. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Mathematics 31A, 31B. Introduction to programming with MATLAB. Applications to numerical methods used in engineering. Letter grading. Ms. Lavine (FW/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 online computer systems to design and display various objects. Letter grading. Mr. Yang (FSp)

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


102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisites: course 101, Mathematics 33A, Physics 1A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in two and three dimensions. Impulse-momentum and work-energy relationships. Applications. Letter grading. Mr. Klug (F, W, Sp)

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading. Mr. Kavehpour, Mr. J. Kim (F, W, Sp)

105A. Introduction to Engineering Thermodynamics. (4) Formerly numbered 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. Piron (F, W, Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20B, Mathematics 32B, 33B. Transport phenomena; heat conduction, mass species diffusion, convective heat and mass transfer, and radiation. Engineering applications in thermal and environmental control. Letter grading. Mr. Ju (F, W, Sp)

107. Introduction to Modeling and Analysis of Dynamic Systems. (3) Lecture, three hours; discussion, one hour; outside study, four hours. Requisites: course 101, or course 107L. Introduction to modeling of physical systems, including mechanical, fluid, thermal, and electrical systems. Linear differential equations. Description of these systems with coverage of superposition, convolution, frequency response, first- and second-order system transient response analysis, and numerical solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response, and numerical solution. Block diagram representation and response of interconnections of systems. Letter grading. Mr. M'Cluskey, Mr. Tsao (F, W, Sp)

107L. Dynamic Systems Laboratory. (1) Laboratory, two hours; outside study, two hours. Requisites: courses 20, 102. Investigation of dynamic behavior of physical systems. Computer simulation and hands-on experiments. Computer-based data acquisition. Time and frequency domain modeling and analysis of mechanical, electrical, thermal, and fluid lumped parameter systems. Letter grading. Mr. M'Cluskey, Mr. Tsao (F, W, Sp)


131AL. Thermodynamics and Heat Transfer Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 131A, 157. Experimental study of physical phenomena and engineering systems using modern data acquisition and processing techniques. Experiments include studies of heat transfer phenomena and testing of a cooling tower, heat exchanger, and internal combustion engine. Students take and analyze data and discuss physical phenomena. Letter grading. Mr. Mills (Sp, alternate years)

132A. Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Principles of mass transfer by diffusion and convection. Simultaneous heat and mass transfer. Analysis of evaporative and transpiration cooling, combustion, and catalysis. Mass exchangers, including automotive catalytic converters, precipitators, filters, scrubbers, humidifiers, and cooling towers. Letter grading. Mr. Mills (F, alternate years)

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A, 105D. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, active and nonactive fluid flow systems. Letter grading. Mr. Catton (F, Sp)

133AL. Power Conversion Thermodynamics Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 133A, 157. Experimental study of power conversion and heat transfer systems using state-of-the-art plant process instrumentation and equipment. Experiments include studies of thermodynamic operating characteristics of an actual Brayton cycle, Rankine cycle, compressive refrigeration unit, and absorption refrigeration unit. Letter grading. Mr. Catton (W, alternate years)

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

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


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

150C. Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 105A, 105D. Chemical thermodynamics of ideal gas mixtures, premixed and diffusive flames, explosions and detonations, combustion chemistry, high explosives. Combustion processes in rocket, turbine, and internal combustion engines; heating applications. Letter grading. Ms. Karagözian, Mr. Smith (W)

150D. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 103. Mechanics of aquatic locomotion; insect and bird flight aerodynamics; pulsatile flow in circulatory system; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial diseases. Letter grading. Mr. Eldredge (F)

150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A, 105D. Chemical thermodynamics of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Letter grading. Ms. Karagözian, Mr. Smith (F)

150R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 103, 105A, 105D. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rockets, and solar-powered vehicles. Current issues in launch vehicle technologies. Letter grading. Ms. Karagözian, Mr. Smith (Sp)

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

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 154S. Classical preliminary design of aircraft, including weight estimation, performance and stability and control. Letter grading. Term assignment consists of preliminary design of low-speed aircraft. Letter grading. Mr. Bendiksen (W)


154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed for design of aircraft. Effects of airplane flexibility on stability derivatives. Letter grading. Mr. Bendiksen (F)

155. Intermediate Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrange equation, variational principles; central force motion; kinematics and dynamics of a rigid body. Euler's formulae. Angular velocity of bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading. Mr. Gibson (F)
156A. Strength of Materials. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisites: courses 101, 182A. Concepts of stress, strain, and material behavior. Stresses in loaded beams with symmetric and asymmetric cross sections, torsion of cylinders and thin-walled structures, shear flow. Stresses in pressure vessels, press-fit and shrink-fit problems, rotating shafts. Curved beams. Contact stresses. Strength and failure, plastic deformation, fatigue, elastic instability. Letter grading. Mr. Mal (F,Sp)

157. Basic Mechanical Engineering Laboratory. (4) Laboratory, four hours; outside, four hours. Requisites: courses 101, 103, 105A, 105D, Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Ghoniem, Mr. Mills (F,WSp)

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 experiments and procedures and use of modern experimental tools and techniques in fluid mechanics. Letter grading. Mr. Kavehpour, Mr. Smith (Sp)

157S. Basic Aerospace Engineering Laboratory. (4) Laboratory, six hours; outside study, four hours. Requisites: courses 101, 102, 103, M105A, Electrical Engineering 100. Recommended: course 15. Measurements of basic physical quantities in fluid mechanics, thermodynamics, and structures. Operation of primary transducers, computer-aided data acquisition, signal processing, and data analysis. Performance of experiments to enhance understanding of basic physical principles and characteristics of structures/systems of relevance to aerospace engineering. Letter grading. Mr. Ju (F,WSp)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102. Recommended: course 182A. Space environment of Earth, trajectories and orbits, 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. Frazzoli (F)

161B. Introduction to Space Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Recommended preparation: courses 102, 105D, 150P, 161A. Propulsion requirements for typical space missions, thermochrometry of propellants, internal ballistics, regenerative cooling, liquid propellant feed systems, POGO instability, Electric propulsion. Multistage rockets, separation dynamics. Satellite structures and materials, loads and vibrations. Thermal control of spacecraft. Letter grading.

Mr. Frazzoli (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 161B. Coverage of preliminary design, by students, of small spacecraft carrying lightweight scientific payload with modest requirements for electric power, lifetime, and attitude stability. Students work in groups of three or four, with each student responsible primarily for one subsystem and for integration with other. Letter grading. Mr. Bendiksen (Sp)

161D. Space Technology Hardware Design. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Recommended requisite or corequisite: course 161B. Design, by students, of hardware with applications to space technology. Designs are then built by HSSEAS professional machine shop and tested by students. New project carried out each year. Letter grading.

Mr. Frazzoli (W)


Mr. Tsao (Sp)

162B. Mechanical Product Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses 162A, 183. Mechanical Engineering 110L. Lecture and laboratory (design) course involving modern design theory and methodology for development of mechanical products. Economics, marketing, manufacturability, quality, and patentability. Design considerations taught and applied to hands-on design project. Letter grading.

Mr. Ghoniem (F,WSp)

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 electromechanical systems and designs. Students build and instrument an assembled machine is instrumented and monitored for operational characteristics. Letter grading.

Mr. Tsao (Sp)

162M. Senior Mechanical Engineering Design. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 131A, 133A, 162B, 168A, 171A. Must be taken in last two academic terms of students’ programs. Analytical course of a large engineering system. Design factors include functionality, efficiency, economy, safety, reliability, aesthetics, and social impact. Final report of engineering specifications and drawings to be presented by design teams. Letter grading.

Mr. Yang (W,Sp)

163A. Introduction to Computer-Controlled Machines. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite or corequisite: course 171A. Modeling of computer-controlled machines, including electrical and electronic elements, mechanical elements, actuators, sensors, and overall electromechanical systems. Motion and command generation, servo-controller design, and computer/machine interfacing. Letter grading.

Mr. Tsao (F)

163A. Analysis of Flight Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 102, 105D, 150P, 161A. Two-dimensional elasticity, stress-strain laws, yield and fatigue; bending of beams; torsion of shafts; warping; torsion of thin-walled cross sections; shear flow, shearing; bending of beams; torsional vibration; stiffened structures used in aerospace vehicles; elements of plate theory; buckling of columns. Letter grading.

Mr. Carmans (F)

168C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, analysis and design examples and design studies, buckling of composite components, nonsymmetric laminates, micromechanics of composites. Letter grading.

Mr. Carmans (W)

168. Introduction to Finite Element Technology. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: courses 20, 101, Mathematics 33A. Recommended: courses 94 or 184, 166A. Introduction to finite element method (FEM) and its matrix formulation of computer implementation of FEM concepts; practical use of FEM codes. Preprocessing and postprocessing techniques; graphics display capabilities; geometric and analysis modeling; interactive engineering systems; links with computer-aided design. Recent trends in FEM technology; design optimization. Term projects using FEM computer codes. Letter grading.

Mr. Klug (Sp)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 102, 182A, Civil Engineering 108. Recommended: Mechanical Engineering 102. Fundamentals of vibration theory and applications. Free, forced, and transient vibration of one and two degrees of freedom systems, including damping, normal modes, coupling, and normal coordinates. Vibration isolation devices, vibrations of continuous systems. Letter grading. Mr. Bendiksen (F,WSp)


Mr. Tsao (Sp)

172. Control System Design Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisite: course 171A. Application of frequency domain design techniques for control of mechanical systems. Successful controller design requires students to formulate performance measures and system stability problems, 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 gyroscopes, and inverted pendulums. Detailed reports required. Letter grading.

Mr. M’Closkey (WSp)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling, Letter grading.

Mr. Shamma (W)

CM180. Introduction to Micromachining and Micromechanical Systems (MEMS). (4) (Formerly numbered M180.) (Same as Biomedical Engineering CM150 and Electrical Engineering CM150.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Corequisite: course CM180L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, sensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM280A. Letter grading.

Mr. C-C. Kim (F)
181A. Complex Analysis and Integral Transforms. (4) (Formerly numbered 191A.) Lecture, four hours; outside study, eight hours. Requisite: course 182A. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals; Laplace transform; properties, convolution, inversion; Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading.

Mr. C.-J. Kim (F)

182A. Mathematics of Engineering. (4) (Formerly numbered 192A.) Lecture, four hours; discussion, two hours; outside study, four hours. Requisite: courses 105, 105B, 131A, 131B. Formulation of general convective heat and mass transfer problem, including equilibrium and nonequilibrium chemistry. Similar and nonsimilar solutions for laminar flows; solution procedures for turbulent flows. Multicomponent diffusion. Application to hypersonic boundary layer, ablation and transpiration cooling. Letter grading.

Mr. Mills (Sp)


Mr. Eldredge, Mr. J. Kim (Sp)


Mr. Zhong (F)


Mr. Hahn, Mr. C.-J. Kim (F,Sp)

184. Introduction to Geometry Modeling. (4) (Formerly numbered 194A.) Lecture, laboratory, eight hours; outside study, four hours. Requisites: courses 20, 94. Fundamentals in parametric curve and surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transformations, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and implementation. Letter grading.

Mr. Yang (W)

185. Computer Numerical Control and Applications. (4) (Formerly numbered 195.) Laboratory, eight hours; outside study, four hours. Designed for juniors/seniors. Fundamentals of numerical control (NC) technology. Programming of computer numerical control (CNC) machines in NC codes and APT language and with CAD/CAM systems. NC postprocessors and distributed numerical control. Operation of CNC lathe and milling machines. Programming and machining of complex engineering parts. Letter grading.

Mr. Yang (Sp)

C167L. Nanoscale Fabrication, Characterization, and Bionanotechnology Laboratory. (2 to 4) Lecture, two hours; laboratory, two hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodegradation. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) nanofabrication, nanocharcaterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create own ideas in self-designed experiments. Concurrently scheduled with course C287L. Letter grading.

Mr. Chen (Sp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) (Formerly numbered 198.) Lecture, two to four hours; outside study, four to eight hours. Special topics in mechanical and aero- space engineering. May be repeated once for credit with instructor change. P/NP or letter grading.

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F,Sp)

Graduate Courses


Ms. Lavine (W)

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Radiative properties of materials and radiative energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation transfer in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading.

Mr. Pinon (W)


Mr. Mills (W)

231F. Advanced Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 231A. Advanced topics in heat transfer from current literature. Focus on applications of current theories to real problems, such as reactor safety, risk-benefit trade-offs, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.

231G. Microsopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electronics, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equations, derivation of classical laws from Boltzmann transport equations, deviation from classical laws at small scale. Letter grading.

Mr. Ju (Sp)

232B. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 132A. Formulation of general convective heat and mass transfer problem, including equilibrium and nonequilibrium chemistry. Similar and nonsimilar solutions for laminar flows; solution procedures for turbulent flows. Multicomponent diffusion. Application to hypersonic boundary layer, ablation and transpiration cooling. Letter grading.

Mr. Eldredge, Mr. J. Kim (Sp)

M237B. Fusion Plasma Physics and Analysis. (4) As an Energy Engineering Lecture, four hours; outside study, eight hours. Requisite: course 188A. Underlying physics and mathematics of nuclear fusion (fusion) core, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transport theory. Letter grading.

Mr. Abdou (Sp)


Mr. Abdou (Sp, alternate years)

239B. Seminar: Current Topics in Transport Phenomena. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, student presentations, and projects in areas of current interest in transport phenomena. May be repeated for credit. S/U grading.

239F. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measurement techniques. May be repeated for credit with topic change. S/U grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest, such as reactor safety, risk-benefit trade-offs, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.
239H. Special Topics in Fusion Physics, Engineering, and Technology. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced treatment of subjects selected from research areas in fusion science and engineering, such as instabilities in burning plasmas, alternate fusion concepts, inertial confinement fusion, fission-fusion hybrid systems, and fusion reactor safety. May be repeated for credit with topic change. S/U grading.

CM240. Introduction to Biomechanics. (4) Same as Biomedical Engineering BME240. (Same as Civil Engineering CE256A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 102, 156A. Introduction to biomechanics of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

Mr. Gupta, Mr. Kablo (W)

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Corequisite: course 182B. Development and fundamental principles of fluid mechanics at graduate level, with emphasis on incompressible flow. Flow kinematics, basic equations, constitutive relations, exact solutions on the Navier/Stokes equations, vorticity dynamics, decomposition of flow fields, potential flow. Letter grading.

Mr. Gupta, Mr. J. Kim (F)

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Fundamental principles of fluid dynamics applied to study of fluid resistance. States of fluid motion discussed in order of advancing Reynolds number; wakes, boundary layers, instability, transition, and turbulent shear flows. Letter grading.

Ms. Karagozian, Mr. J. Kim (W)

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Effects of compressibility in viscous and inviscid flows. Steady and unsteady inviscid subsonic and supersonic flows; method of characteristics; small disturbance theories (linearized and hypersonic); shock dynamics. Letter grading.

Ms. Karagozian, Mr. Zhong (Sp)

250D. Computational Aerodynamics. (4) Lecture, eight hours. Requisites: courses 150A, 150B, 182C. Introduction to basic concepts and techniques of various spectral methods applied to solving partial differential equations. Particular emphasis on techniques of solving unsteady three-dimensional Navier/Stokes equations. Topics include spectral representation of functions, discrete Fourier transform, etc. Letter grading.

Mr. J. Kim (Sp, alternate years)


Mr. Zhong (W, alternate years)

250F. Hypersonic and High-Temperature Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 182A, 182B, 182C. Hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermodynamics for calculation gas properties, equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermodynamics for calculation gas properties, equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermodynamics for calculation gas properties. Letter grading.

Mr. Zhong (W)

250G. Introduction to Microfluids/Nanofluids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Introduction to fundamentals of microfluidics, nano- and microfluidic devices, experimental techniques, and applications of microfluidics. Letter grading.

252A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Mechanisms by which laminar flows can become unstable and lead to turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; boundary layer instability. Nonlinear aspects: sufficient criteria for stability, subcritical instabilities, supercritical states, transition to turbulence. Letter grading. Mr. Zhong (W, odd years)


Mr. Karagozian (F, odd years)


Ms. Karagozian (F, odd years)

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: molecular collisions, distribution functions and averaging, semiemipirical 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 bound- ed media; Ray acoustics; attenuation mechanisms in fluids. Letter grading.

Mr. Eldredge


254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 182A, 182B, 182C. Special topics of current interest in advanced aerodynamics. Examples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamic flows. Letter grading.

Mr. Zhong

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 156A. Variational principles and Lagrange equations. Kinematics and dynamics; procession and nutation of spinning bodies. Letter grading.

Mr. Frazzoli (W)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Concepts of stability, state-space representation, linearization, and Lyapunov direct method; the Hamiltonian as a Lyapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and nonlinear resonance. Application to mechanical systems. Letter grading. Mr. M’Closkey (Sp, odd years)

M256A. Linear Elasticity. (4) (Formerly numbered 256A.) (Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading.

Mr. Mal (F)

M256B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stresses, Cauchy equations of motion, relations between the Noether and Lagrange formulations; constitutive relations, elasticity, hyperelasticity, thermoelasticity; linearization of field equations; solution of selected problems. Letter grading. Mr. Dong, Mr. Mal (W)


Mr. Mal (F)

255F. Analytical Fracture Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 156A or 166A, Materials Science 243A. Review of modern fracture mechanics, elementary stress analyses; analytical and numerical methods for calculation of crack tip stress intensity factors; engineering applications in strengthened structures, pressure vessels, plates, and shells. Letter grading.

Mr. Gupta (Sp)

M257A. Elastodynamics. (4) Same as Earth and Space Sciences M224A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equa- tion of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves in unbounded isotropic, anisotropic, and dissipa- tive 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)
258A. Nanomechanics and Micromechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materials at scales ranging from atomic through microstructure or transitional and up to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics, Langevin dynamics, and kinetic Monte Carlo) and their applications at nanoscale. Development and applications of dislocation dynamics and statistical mechanics methods in areas of nanostructure and microstructure self-organization, heterogeneous plastic deformation, material instabilities, and failure phenomena. Presentation of technical applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultranano nanolayer materials), nano-identification, smart (active) materials, nanobending and microbending, and torsion. Letter grading. Mr. Ghoniem (F)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assignments in research problems leading to term paper or oral presentation (possible help from guest lecturers). Letter grading. Mr. Smith (W, alternate years)

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid mechanics. Topics selected from continuum mechanics, dynamics, and kinetic Monte Carlo. 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.


262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 166C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology. Micro/macro analysis, including classical lamination theory, shear lag theory, concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems design, inch-worm, and bimorph. Letter grading. Mr. Carman (W)

263A. Analytical Foundations of Motion Controllers. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: courses 163A, 294. Theory of motion control for robots, computer-controlled machines; multiaxis computer-controlled machines; machine kinematics and dynamics; multiaxis motion coordination; coordinated motion with desired speed, acceleration, and jerk in joint and multiaxis command generation; theory and design of controller interprocessors; motion trajectory design and analysis; geometry-speed-sampling time relationships. Letter grading. Mr. Yang (W)

263B. Spacecraft Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Recommended: course 255B. Modeling, dynamics, and stability of spacecraft; spinning and dual-spin spacecraft dynamics; spinup through resonance, spinning rocket dynamics; environmental torques in space, modeling and model reduction of flexible space structures. Letter grading. Mr. Frizzo (Sp, alternate years)

263C. Mechanics and Trajectory Planning of Industrial Robots. (4) Lecture, four hours; outside study, eight hours. Requisite: course 163A. Theory and implementation of industrial robots. Design considerations, kinematic 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, 171A, 263C. Motion planning and control of articulated dynamic systems: nonlinear joint control, experiments in joint control and multiaxis coordination, multibody dynamics, trajectory planning, motion optimization, dynamic performance and manipulator design, kinemadic redundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading. Mr. Hahn (Sp) M269A. Dynamics of Structures. (4) (Same as Civil Engineering M237A.) Lecture, four hours; outside study, eight hours. Requisite: course 169A. Principles of dynamics. Determination of normal modes and frequencies by differential and integral equation solutions. Transient and steady state response. Emphasis on derivation and solution of governing equations using matrix formulation. Letter grading. Mr. Bendiksen (W)

269B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Analysis and nonlinear response of structures to dynamic loads. Stresses and deflections in structures. Structural damping and self-induced vibrations. Letter grading. Mr. Bendiksen (Sp, alternate years)

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aeroelasticity from unified viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow induced instability and response of structural systems. Letter grading. Mr. Bendiksen (F, alternate years) M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engineering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course 171A or Electrical Engineering 141. State-space description of linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular values, Cayley-Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Concepts with transfer function techniques. Letter grading. Mr. Gibson (F)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stabilization, observability, and detectability solutions. Letter grading. Mr. Gibson (F) M270C. Optimal Control. (4) (Same as Chemical Engineering M280C and Electrical Engineering M240C.) Lecture, four hours; outside study, eight hours. Requisite: course 270B. Applications of variational methods, Pontryagin maximum principle, Hamilton-Jacobi-Bellman equation (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. Mr. Speyer (Sp)


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 dynamical systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical Engineering M242A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M280A or Electrical Engineering M240A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamical systems with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading. Mr. Shamma (Sp)

272A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M’Closkey (Sp)
275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Methods for identification of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include transfer functions and state-space models. Discussion of applications of mechanical, aerospace engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading.

M276. Dynamic Programming. (4) (Same as Electrical Engineering M237.) Lecture, four hours; outside study, eight hours. Recommended requisite: Electrical Engineering 232A or 236A or 236B. Introduction to mathematical models of 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. Shamah (Sp)

CM280A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Formerly numbered M280.) (Same as Biomedical Engineering CM250A and Electrical Engineering CM250A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL; Corequisite: course CM280L. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Architectures of micromachining and lithography methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS devices. Concurrently scheduled with course CM180. Letter grading. Mr. C.-J. Kim (W)

CM280L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Paralleled with course CM280A.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL; Corequisite: course CM280A. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM180L. Letter grading. Mr. C.-J. Kim (W)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Basic science issues in micro domain. Topics include micro fluid science, microscale heat transfer, mechanical behavior of microstructures, as well as dynamics and control of micro devices. Letter grading.

Mr. Ho, Mr. C.-J. Kim (F)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Biomedical Engineering M250B and Electrical Engineering M250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M280. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. C.-J. Kim (Sp)

283. Experimental Mechanics for Microelectromechanical Systems (MEMS). (4) Lecture, four hours; outside study, eight hours. Methods, techniques, and philosophies being used to characterize microelectromechanical systems for engineering applications. Material characterization, mechanical/material properties, mechanical characterization. Topics include fundamentals of crystallography, anisotropic material properties, and mechanical behavior (e.g., strength/ fracture/fatigue) as they relate to microscale. Considerable emphasis on 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. Prerequisites: electronics, computer programming experience. Applications of using unique properties of micro transducers for distributed and real-time control of engineering problems. Associated signal processing requirements for these applications. Letter grading. Mr. Ho (W, alternate years)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 105A, 105D, 182A. Introduction to fundamental physical phenomena governing interfacial structures and application of their knowledge to engineering problems. Fundamental concepts of interfacial phenomena, including surface and interfacial properties, interfacial thermodynamics, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (blisters of crystallography, anisotropic material simulations, microelectromechanical systems, and biological systems. Letter grading. Mr. Pilon (F)

286. Molecular Dynamics Simulation. (4) Lecture, four hours; outside study, eight hours. Preparation: computer programming experience. Requisites: courses 182A, 182C. Introduction to basic concepts and methodologies of molecular dynamics simulation. Advantages and disadvantages of this approach for various engineering problems. Emphasis on simulations of engineering interest, especially microscopic fluid mechanics, heat transfer, and solid mechanics problems. Letter grading. Mr. Kavehpour (W)

M287. Nanoscience and Technology. (4) (Same as Electrical Engineering M257.) Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nano-fabrication; nanocharacterization; nanomaterials, nanoelectronics, and nanobiodetection technology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading. Mr. Chen (W)

C287L. Nanoscale Fabrication, Characterization, and Biodeformation Laboratory. (2 to 4) Lecture, two hours; laboratory, two hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) nano-fabrication, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C187L. Letter grading. Mr. Chen (Sp)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 14, Physics 17. Science and engineering of laser microfabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (therma, mass, chemical, current, 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 184. Computationally intensive design. For students interested in special emphasis on emerging computational geometry, modeling of curves and surfaces, B-splines and NURBS. Compose curves and surfaces, computer methods for surface design and manufacture, and current research topics in computational geometry for CAD/CAM systems. Letter grading. Mr. Yang (W)


295B. Internet-Based Collaborative Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 94, 184. Exploration of advanced state-of-the-art concepts in Internet-based collaborative design. For students interested in connecting designers over Internet, networked variable media graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mobile device-based systems, and multifunctional design collaboration and software tools to support it. Letter grading. Mr. Gadh (W)

295C. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. Mr. Gadh (W)

296A. Damage and Failure of Materials in Mechanical Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course 156A. Materials Science 143A. Role of failure prevention in mechanical design and case studies. Mechanics and physics of material imperfections: voids, dislocations, cracks, and inclusions. Statistical and deterministic design methods. Plastic, fatigue, and creep damage. Letter grading. Mr. Ghomiem (Sp, alternate years)
Schoolwide Programs, Courses, and Faculty

UCLA
6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
(310) 825-2826
http://www.engineer.ucla.edu

Professors Emeriti
Edward P. Coleman, Ph.D.
Allen B. Rosenstein, Ph.D.
Bonham Spence-Campbell, E.E.

Graduate Study
For information on graduate admission to the schoolwide engineering programs and requirements for the Engineer degree and certificate of specialization, see Graduate Programs, page 24.

Faculty Areas of Thesis Guidance
Professors Emeriti
Edward P. Coleman, Ph.D. (Columbia U., 1951)
Design of experimentation; operations management, environment; process of product reliability and quality
Allen B. Rosenstein, Ph.D. (UCLA, 1958)
Educational delivery systems, computer-aided design, design, automatic controls, magnetic controls, nonlinear electronics
Bonham Spence-Campbell, E.E. (Cornell, 1939)
Development of interdisciplinary engineering/social science teams and their use in planning and management of projects and systems

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

87. Introduction to Engineering Disciplines. (4) Formerly numbered 97.) Lecture, four hours; discussion, four hours; outside study, four hours. Introduc-
tion to engineering as professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers per-
form. Development of skills and techniques for academic excellence through team process. Invention of national need underlying current effort to in-
crease participation of historically underrepresented groups in the U.S. technological work force. Letter grading.

Graduate Courses
200. Program Management Principles for Engi-
neers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate stu-
dents. Practical review of necessary processes and procedures to successfully manage technology pro-
grams. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manag-
ers with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading.

95. Ethical and Professional Issues in Engineer-
ing 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 in-
volve conflicting demands on society. Letter grading.

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for low-
er division students under guidance of faculty mentor. Students must be in good academic standing and en-
rolled in minimum of 10 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses
183. Engineering and Society. (4) Formerly num-
bered 193.) Lecture, four hours; discussion, two hours; outside study, six hours. Limited to junior/senior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and on development of moral and ethical values. Contemporary environmental, bi-
ological, legal, and other issues created by new tech-
nologies. Letter grading.

185. Art of Engineering Endeavors. (4) Formerly numbered 195.) Lecture, four hours; discussion, two hours; outside study, six hours. Directed studies for seniors. Importance of group dynamics in engineering prac-
tice. Teamwork and effective skills in engineering environments. Organization and control of multi-
disciplinary complex engineering projects. Forms of leadership and qualities and characteristics of effec-
tive leaders. How engineering, computer sciences, and technology relate to major ethical and social is-

188. Special Courses in Engineering. (4) Semi-
inar, four hours; outside study, eight hours. Special topics in engineering for undergraduate students that are taught on experimental or temporary basis, such as those taught by resident and visiting faculty mem-
bers. May be repeated once for credit with topic or in-
structor change. Letter grading.

195. Internship Studies in Engineering. (4) For-
merly numbered 195L.) Tutorial, four hours. Limited to juniors/seniors. Internship studies course supervised by associate dean or designated faculty members. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with in-
structor and provide periodic reports of their experi-
ence. May not be applied toward major requirements. Normally, only 4 units of internship are allowed. Indi-
vidual contract with associate dean required. P/NP grading.

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

Mr. O’Neill

Ms. Lavine (F, W, Sp)
Mr. Hahn (Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)

Mr. Jacobsen (F, W, Sp)
201. Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements: system requirements and flow down, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and documentation. Letter grading. (W)

210. Entrepreneurship for Engineers. (4) Lecture, three hours. Limited to graduate engineering students. Topics in starting and developing high-tech enterprises and intended for students who wish to complement their technical education with introduction to entrepreneurship. Letter grading.

Mr. Abe, Mr. Cong, Mr. Jacobsen (W)

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


471A-471B-471C. The Engineer in the General Environment. (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading; In Progress (471B) and S/U or letter (471C) grading.

472A-472D. The Engineer in the Business Environment. (3-3-1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Language of business for the engineering executive. Accounting, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (472A, 472C) and S/U or letter grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of a Large-Scale System. (3-3) Lecture, two and one-half hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for a goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as a teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. (F)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Used to record enrollment of UCLA students in courses taken under cooperative arrangements with USC. S/U grading.
Research Centers, Laboratories, and Institutes

Center for Embedded Networked Sensing
National Science Foundation Science and Technology Center
Deborah Estrin (Computer Science), Director; http://www.cens.ucla.edu
UCLA’s Center for Embedded Networked Sensing (CENS) is a major research enterprise developing wireless sensor systems and applying this revolutionary technology to radically transform critical scientific and societal applications. Expanding on the concept of the Internet, these large-scale distributed systems, composed of smart wireless sensors and actuators embedded in the physical world, will eventually connect the entire physical world to the virtual world. Embedded networked sensing systems can reveal previously unobservable phenomena through the use of adaptive, self-configuring wireless systems that enable spatially and temporally dense monitoring of challenging physical environments. This new technology will revolutionize biological and physical sciences, including tracking ecosystem dynamics and large-scale, real-time monitoring of seismic events. The center forms a cornerstone for new transdisciplinary partnerships, such as creating innovative formats for film, theater, and digital media arts and enabling remote monitoring of patients’ health. CENS hopes to have a significant impact on gender disparities in science and engineering at UCLA, providing increased hands-on research opportunities for undergraduate students, and middle and high school students.

Center for Nanoscience Innovation for Defense
Defense Advanced Research Project Agency/Defense MicroElectronics Activity
Eli Yablonovitch (Electrical Engineering), Director
The Center for Nanoscience Innovation for Defense (CNID) was established to facilitate the rapid transition of research innovation in the nanosciences into applications for the defense sector. With nationally renowned faculty employing interdisciplinary approaches, the center brings discovery and innovation in nanoscience and nanoengineering to America’s industries for the purpose of defense. The center’s research program seeks to understand and thereby control nanometer-scale systems for advanced technology. Research at UCLA focuses on four areas: quantum telecommunication nanodevices, development of a single-electron spin microscope, photonic crystal nanooptical structures and circuits, and molecular level electronic and mechanical devices. Funding through CNID will help equip the California NanoSystems Institute with state-of-the-art high-tech instrumentation, and also support graduate fellowships that will attract the best graduate students worldwide to advance nanoscience and nanotechnology research. Those students will be not only the nanoscience university researchers of the future, but also the nanotechnology talent for high-tech American businesses.

Center for Scalable and Integrated Nanomanufacturing
National Science Foundation Nanoscale Science and Engineering Center
Xiang Zhang, Director (UC Berkeley); Eli Yablonovitch, (Electrical Engineering), Co-Director; http://www.sinam.ucla.edu
The promise that nanotechnology holds for industries ranging from semiconductors to healthcare to national defense has largely been held back by the lack of manufacturing platforms that allow complex nanoengineered products and systems to be adopted on a mass scale. UCLA’s Center for Scalable and Integrated Nanomanufacturing (SINAM) is bridging the gap between scientific research and economically feasible manufacturing solutions. SINAM researchers will combine fundamental science and nanomanufacturing technology in new ways, transforming laboratory science into industrial applications in nanoelectronics and biomedicine. A multidisciplinary team of researchers will devise commercial nanomanufacturing tool designs and build them into systems that will enable cost-effective nanomanufacturing. A better understanding of the nano world will lead to more powerful microscopes, groundbreaking nanofabrication technologies, and exciting new applications in information technology and medicine.

Flight Systems Research Center
A.V. Balakrishnan (Electrical Engineering), Director; http://fsrc.ee.ucla.edu
The Flight Systems Research Center, established in 1985 under a Memorandum-of-Agreement with the NASA Ames/Dryden Flight Research Facility, is devoted to interdisciplinary research in flight systems and related technologies. Faculty from the Computer Science, Electrical Engineering, Mathematics, and Mechanical and Aerospace Engineering Departments are currently associated with the center. Current research projects include:

• Viscous flow simulation of boundary layer instability and transition in supersonic swept wing flows
• Embedded optical sensor research with applications to flight
• Research studies for flight systems of the future
• Aircraft finite element model validation based on ground vibration test data
• Development of a compact ultrasonic piezohydraulic actuator for control surface articulation
• Support of the development of a neural net flight air data system
• Development of probabilistic risk assessment models of UAVs
• Self-aware sensor networks
• Shape memory alloys for trailing-edge wing flaps or trim tabs
• CFD calculations of shock oscillations in transonic flow over active aeroelastic wings
• In-flight leak detection systems
• Control of high-speed jet mixing and reaction processes
• Mathematical theory of aeroelasticity
• Application of stochastic filtering and control methodology to the optimization of wind turbine control design
Functional Engineered Nano Architectonics Focus Center

Microelectronic Advanced Research Corporation Focus Center
Kang L. Wang (Electrical Engineering), Director; Bruce Dunn (Materials Science and Engineering), Co-Director; http://www.fena.org

Dramatic advances in nanotechnology, molecular electronics, and quantum computing are creating the potential for significant expansion of current semiconductor technologies. Researchers at UCLA will make pioneering contributions to these fields through the Functional Engineered Nano Architectonics Focus Center (FENA) funded by the Semiconductor Research Association and the Department of Defense.

The term “architectonics” is derived from a Greek word meaning master builder—an apt description of the center’s researchers as they build a new generation of nanoscale materials, structures, and devices for the electronics industry. The FENA team will explore the challenges facing the semiconductor industry as the electronic devices and circuits that power today’s computers grow ever smaller. With more and more transistors and other components squeezed onto a single chip, manufacturers are rapidly approaching the physical limits posed by current chip-making processes. Researchers seek to resolve a number of issues related to post-CMOS technologies that will allow them to extend semiconductor technology further into the realm of the nanoscale.

Institute for Cell Mimetic Space Exploration

A NASA University Research, Engineering, and Technology Institute
Chih-Ming Ho (Mechanical and Aerospace Engineering), Director; Carlo Montemagno (Bioengineering), Co-Director; http://www.cmise.ucla.edu

The Institute for Cell Mimetic Space Exploration (CMISE) is realizing a unique approach by fusing biotechnology, nanotechnology, and information science to enrich the development of revolutionary application-specific technologies. For example, a cell fuses genetic processes with nanoscale sensors and actuators to result in an efficient, autonomous micro “factory.” The basic processes that occur at the molecular level have opened up a world where the integration of individual components can eventually derive higher-order functionalities or emergent properties. The fusion of biotechnology, nanotechnology, and informatics will culminate in systemic architectures that will rival those that have taken millions of years to come to fruition in nature. CMISE researchers also hope to achieve a fundamental comprehension of how the interplay of these three areas can be manipulated on the molecular level to produce enhanced, emergent properties.

CMISE is organized into four interdisciplinary research groups: energetics, metabolics, systematics, and CMISESat. The energetics group harnesses and transforms energy across a range of disciplines, while the metabolics team develops nano/micro systems for single-cell metabolism study and network reconstruction of radiation damage to cells. The systematics group enables intelligent cell mimetic systems, and monitors and controls artificial and biological subsystems. The CMISESat team provides the space testbed environment for validation and demonstration of emerging CMISE technologies.

Institute of Plasma and Fusion Research

Mohamed A. Abdou (Engineering) and Alfred Wong (Physics), Co-Directors; 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.
Western Institute of Nanoelectronics
A Nanoelectronics Research Initiative
National Institute of Excellence
Kang L. Wang (Electrical Engineering),
Director; http://win-nano.org
The Western Institute of Nanoelectronics (WIN), one of the world’s largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically-needed innovations in semiconductor technology. A National Institute of Excellence, WIN leverages what are considered the best interdisciplinary nanoelectronics talents in the world to explore and develop advanced research devices, circuits, and nanosystems with performance beyond conventional CMOS devices. The pioneering new technology of spintronics relies on the spin of an electron to carry information, and holds promise in minimizing power consumption for next-generation electronics.

As rapid progress in the miniaturization of semiconductor electronic devices leads toward chip features smaller than 100 nanometers in size, researchers have had to begin exploring new ways to make electronics more efficient. Today’s devices, based on CMOS standards, cannot get much smaller and still function effectively. Information-processing technology has so far relied on charge-based devices, ranging from vacuum tubes to million-transistor microchips. Conventional electronic devices simply move these electric charges around, ignoring the spin on each electron. Spintronics aims to put that extra spin action to work—effectively corralling electrons into one smooth chain of motion.
### B.S. in Aerospace Engineering Curriculum

#### FRESHMAN YEAR

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<th>Course</th>
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<td>English Composition 3 – English Composition, Rhetoric, and Language</td>
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<td>Mathematics 32A – Calculus of Several Variables</td>
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#### TOTAL 187

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#### SOPHOMORE YEAR

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<td>Mathematics 32B – Calculus of Several Variables</td>
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<td>Physics 1C – Electrodynamics, Optics, and Special Relativity</td>
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<td>Physics 4BL – Electricity and Magnetism Laboratory</td>
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<td>Materials Science and Engineering 104 – Science of Engineering Materials</td>
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<td>Mathematics 33A – Linear Algebra and Applications</td>
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<td>Mechanical and Aerospace Engineering 105A – Introduction to Engineering Thermodynamics</td>
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<td>Mechanical and Aerospace Engineering 166A – Analysis of Flight Structures</td>
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<td>Mechanical and Aerospace Engineering 154A – Preliminary Design of Aircraft</td>
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<td>Mechanical and Aerospace Engineering 154B – Design of Aerospace Structures</td>
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</table>

**TOTAL 187**

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*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
†A total of 8 units of aerospace engineering electives (two courses) is required.
# B.S. in Bioengineering Curriculum

## FRESHMAN YEAR

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<td>Mathematics 31A – Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B – Chemical Energetics and Change</td>
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<td>Physics 1A – Mechanics</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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## SOPHOMORE YEAR

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<td>Life Sciences 2 – Cells, Tissues, and Organs</td>
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## JUNIOR YEAR

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<td>Bioengineering 182A – Bioengineering Capstone Design I</td>
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<td>Bioengineering 165 – Bioethics and Regulatory Policies in Bioengineering</td>
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<td>Bioengineering 181/181L – System Integration in Biology, Engineering, and Medicine II/Laboratory</td>
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<td>Bioengineering 182B – Bioengineering Capstone Design II</td>
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<td>Bioengineering 182C – Bioengineering Capstone Design III</td>
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*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
†See page 26 for a list of approved electives.
## B.S. in Chemical Engineering Curriculum

### FRESHMAN YEAR

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<td>Mathematics 31A – Differential and Integral Calculus</td>
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<td>Computer Science 31 – Introduction to Computer Science I</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>Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>Chemistry and Biochemistry 30B – Organic Chemistry: Reactivity and Synthesis, Part I</td>
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# B.S. in Chemical Engineering
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# B.S. in Chemical Engineering
## Biomolecular Option Curriculum

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<th>Units</th>
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<tr>
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<td>Chemical Engineering 104B – Chemical and Biomolecular Engineering Laboratory II</td>
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<td>Chemical Engineering 106 – Chemical Reaction Engineering</td>
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<tr>
<td>2nd</td>
<td>Chemical Engineering 107 – Process Dynamics and Control</td>
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<td>Chemical Engineering 108A – Process Economics and Analysis</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>3rd</td>
<td>Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis</td>
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**TOTAL** 192

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
# B.S. in Chemical Engineering

## Semiconductor Manufacturing Option Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
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<th>Course Description</th>
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<td>Chemical Engineering 10 – Introduction to Chemical and Biomolecular Engineering</td>
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<td>Chemistry and Biochemistry 20A – Chemical Structure</td>
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<td>Mathematics 31A – Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B – Chemical Energetics and Change</td>
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<tr>
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<td>Computer Science 31 – Introduction to Computer Science I</td>
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<td></td>
<td>Mathematics 31B – Integration and Infinite Series</td>
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<td>Physics 1A – Mechanics</td>
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<tr>
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<td>Chemistry and Biochemistry 20L – General Chemistry Laboratory</td>
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<td></td>
<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>Chemistry and Biochemistry 113A – Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemistry and Biochemistry 30B – Organic Chemistry: Reactivity and Synthesis, Part I</td>
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<td>Mathematics 33A – Linear Algebra and Applications</td>
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<td>Chemistry and Biochemistry 153A – Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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<td>Mathematics 33B – Differential Equations</td>
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### JUNIOR YEAR

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<td>Chemical Engineering 100 – Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Chemical Engineering 101A – Transport Phenomena I</td>
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<td>Chemical Engineering 109 – Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101B – Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 102A – Thermodynamics I</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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### SENIOR YEAR

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<td>Chemical Engineering C116 – Surface and Interface Engineering</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>Chemical Engineering 104C/104CL – Semiconductor Processing/Laboratory</td>
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<td>Chemical Engineering 108B – Chemical Process Computer-Aided Design and Analysis</td>
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</table>

**TOTAL** 192

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
## B.S. in Civil Engineering Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
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<th>Course</th>
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<tr>
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<td>English Composition 3 – English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A – Differential and Integral Calculus</td>
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<td>Physics 1A – Mechanics</td>
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<td>4th</td>
<td>Mathematics 32A – Calculus of Several Variables</td>
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<td>Physics 1B – Oscillations, Waves, Electric and Magnetic Fields</td>
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### SOPHOMORE YEAR

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<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 101 – Statics and Dynamics</td>
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<td>Civil and Environmental Engineering 15 – Introduction to Computing for Civil Engineers</td>
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<td>Civil and Environmental Engineering 108 – Introduction to Mechanics of Deformable Solids</td>
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<td>Mathematics 33A – Linear Algebra and Applications</td>
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### JUNIOR YEAR

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<tr>
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<td>Civil and Environmental Engineering 120 – Principles of Soil Mechanics</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 182A – Mathematics of Engineering</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A</td>
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<td>Civil and Environmental Engineering 103 – Applied Numerical Computing and Modeling in Civil</td>
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<td>Environmental Engineering</td>
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<td>Civil and Environmental Engineering 151 – Introduction to Water Resources Engineering</td>
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<td>Civil and Environmental Engineering 110 – Introduction to Probability and Statistics for</td>
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### SENIOR YEAR

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<td>Major Field Electives (2)*</td>
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### TOTAL

188, 189, or 190

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
†Must include required courses for two of the major field areas listed on page 46.
# B.S. in Computer Science Curriculum

## Freshman Year

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<td>Computer Science 1 – Freshman Computer Science Seminar</td>
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<td>Computer Science 31 – Introduction to Computer Science I</td>
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<td>Mathematics 31A – Differential and Integral Calculus</td>
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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 – Integration and Infinite Series</td>
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<td>Physics 1A – Mechanics</td>
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<tr>
<td>3rd</td>
<td>Computer Science 33 – Introduction to Computer Organization</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>Mathematics 31A – Differential and Integral Calculus</td>
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## Sophomore Year

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<td>Electrical Engineering 1 – Electrical Engineering Physics I</td>
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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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<tr>
<td>2nd</td>
<td>Computer Science M51A or Electrical Engineering M16 – Logic Design of Digital Systems</td>
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<td>Mathematics 33A – Linear Algebra and Applications</td>
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<td>Mathematics 61 – Introduction to Discrete Structures</td>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td>3rd</td>
<td>Computer Science 101 – Upper Division Computer Science Seminar</td>
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<td>Computer Science 131 – Programming Languages</td>
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<td>Computer Science M152A or Electrical Engineering M116L – Introductory Digital Design Laboratory</td>
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<td>Mathematics 33B – Differential Equations</td>
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## Junior Year

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<tr>
<td>1st</td>
<td>Computer Science M151B or Electrical Engineering M116C – Computer Systems Architecture</td>
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<td>Computer Science 180 – Introduction to Algorithms and Complexity</td>
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<td>Computer Science 130 (Software Engineering) or M152B (or Electrical Engineering M116D – Digital Design Project Laboratory)</td>
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<td>HSSEAS GE Elective*</td>
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<td>Science and Technology Elective</td>
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<tr>
<td>3rd</td>
<td>Computer Science 111 – Operating Systems Principles</td>
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<td>Statistics 110A – Applied Statistics</td>
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<td>Breadth Course*</td>
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## Senior Year

<table>
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<th>Course Name</th>
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<tbody>
<tr>
<td>1st</td>
<td>Computer Science 118 – Computer Network Fundamentals</td>
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<td>Computer Science 181 – Introduction to Formal Languages and Automata Theory</td>
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<td>Breadth Course*</td>
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<td>Computer Science Elective</td>
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<td>2nd</td>
<td>Breadth Course*</td>
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<td>Science and Technology Elective</td>
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</table>

**Total**: 186

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
# B.S. in Computer Science and Engineering Curriculum

## FRESHMAN YEAR

### 1st Quarter
- Chemistry and Biochemistry 20A – Chemical Structure .................................................. 4
- Computer Science 1 – Freshman Computer Science Seminar ............................................. 1
- Computer Science 31 – Introduction to Computer Science I ............................................... 4
- Mathematics 31A – Differential and Integral Calculus ...................................................... 4

### 2nd Quarter
- Computer Science 32 – Introduction to Computer Science II ........................................... 4
- English Composition 3 – English Composition, Rhetoric, and Language ............................. 5
- Mathematics 31B – Integration and Infinite Series ............................................................ 4
- Physics 1A – Mechanics ....................................................................................................... 5

### 3rd Quarter
- Computer Science 33 – Introduction to Computer Organization ....................................... 5
- Mathematics 32A – Calculus of Several Variables .............................................................. 4
- Physics 1B – Oscillations, Waves, Electric and Magnetic Fields ......................................... 5
- Physics 4AL – Mechanics Laboratory .................................................................................. 2

## SOPHOMORE YEAR

### 1st Quarter
- Computer Science 35L – Software Construction Laboratory ............................................. 2
- Electrical Engineering 1 – Electrical Engineering Physics I .................................................. 4
- Mathematics 32B – Calculus of Several Variables ............................................................... 4
- Physics 4BL – Electricity and Magnetism Laboratory ........................................................... 2
- HSSEAS GE Elective* ........................................................................................................... 5

### 2nd Quarter
- Computer Science M51A or Electrical Engineering M16 – Logic Design of Digital Systems 4
- Mathematics 33A – Linear Algebra and Applications .......................................................... 4
- Mathematics 61 – Introduction to Discrete Structures .......................................................... 4
- HSSEAS GE Elective* ........................................................................................................... 5

### 3rd Quarter
- Computer Science 101 – Upper Division Computer Science Seminar .............................. 1
- Computer Science M152A or Electrical Engineering M116L – Introductory Digital Design Laboratory 2
- Electrical Engineering 2 – Physics for Electrical Engineers .................................................. 4
- Mathematics 33B – Differential Equations ......................................................................... 4
- Statistics 110A – Applied Statistics ..................................................................................... 4

## JUNIOR YEAR

### 1st Quarter
- Computer Science 131 – Programming Languages ............................................................. 4
- Computer Science M151B or Electrical Engineering M116C – Computer Systems Architecture 4
- Electrical Engineering 10 – Circuit Analysis I .................................................................... 4
- HSSEAS GE Elective* ........................................................................................................... 4

### 2nd Quarter
- Computer Science 111 – Operating Systems Principles ..................................................... 4
- Computer Science 180 – Introduction to Algorithms and Complexity ................................ 4
- Electrical Engineering 102 – Systems and Signals .............................................................. 4
- Electrical Engineering 110 – Circuit Analysis II ................................................................. 4

### 3rd Quarter
- Computer Science 181 – Introduction to Formal Languages and Automata Theory .......... 4
- Electrical Engineering 110L – Circuit Measurements Laboratory ...................................... 2
- Electrical Engineering 115A – Analog Electronic Circuits I .................................................. 4
- Breadth Course* ................................................................................................................... 4

## SENIOR YEAR

### 1st Quarter
- Computer Science 118 – Computer Network Fundamentals .............................................. 4
- Computer Science M152B or Electrical Engineering M116D – Digital Design Project Laboratory 4
- Electrical Engineering 115C – Digital Electronic Circuits ................................................... 4
- Computer Science Elective .................................................................................................... 4

### 2nd Quarter
- Breadth Course* ................................................................................................................... 4
- Computer Science Electives (2) .............................................................................................. 8
- HSSEAS GE Elective* ........................................................................................................... 5

### 3rd Quarter
- Breadth Course* ................................................................................................................... 4
- HSSEAS GE Elective* ........................................................................................................... 4
- HSSEAS GE Elective* ........................................................................................................... 5

**TOTAL** 188

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
**B.S. in Electrical Engineering Curriculum**

### FRESHMAN YEAR

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<tr>
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<tr>
<td>Electrical Engineering 141 – Principles of Feedback Control</td>
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### SOPHOMORE YEAR

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<tr>
<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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### JUNIOR YEAR

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<td>Electrical Engineering 113 – Digital Signal Processing</td>
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<td>Electrical Engineering 131A – Probability</td>
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<td>Electrical Engineering 115A – Analog Electronic Circuits I</td>
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<td>Mathematics 132 – Complex Analysis for Applications</td>
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<td>Electrical Engineering 121B – Principles of Semiconductor Device Design</td>
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<td>Electrical Engineering 132A – Introduction to Communication Systems</td>
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<tr>
<td>Electrical Engineering 161 – Electromagnetic Waves</td>
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### SENIOR YEAR

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<td>HSSEAS GE Elective*</td>
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<tr>
<td>Pathway Elective†</td>
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**TOTAL** 187

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
†See page 73 for a list of approved pathways.
# Biomedical Engineering Option Curriculum

**B.S. in Electrical Engineering**

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<th>FRESHMAN YEAR</th>
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<tr>
<td>Chemistry and Biochemistry 20A – Chemical Structure</td>
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<td>Computer Science 31 – Introduction to Computer Science I</td>
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<td>Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>English Composition 3 – English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31B – Integration and Infinite Series</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>Chemistry and Biochemistry 30AL – General Chemistry Laboratory II</td>
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<td>Mathematics 32A – Calculus of Several Variables</td>
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<td>Physics 1A – Mechanics</td>
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**Sophomore Year**

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<tr>
<td>Electrical Engineering M6 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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<tr>
<td>Physics 1B/4AL – Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>Electrical Engineering 1 – Electrical Engineering Physics I</td>
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<td>Life Sciences 2 – Cells, Tissues, and Organs</td>
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<tr>
<td>Physics 4BL – Electricity and Magnetism Laboratory</td>
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<td>Electrical Engineering 2 – Physics for Electrical Engineers</td>
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<tr>
<td>Electrical Engineering 102 – Systems and Signals</td>
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<tr>
<td>Electrical Engineering 103 – Applied Numerical Computing</td>
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<td>Mathematics 33B – Differential Equations</td>
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**Junior Year**

<table>
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<td>Electrical Engineering 10 – Circuit Analysis I</td>
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<tr>
<td>Electrical Engineering 113 – Digital Signal Processing</td>
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<td>Electrical Engineering 131A – Probability</td>
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<tr>
<td>Life Sciences 3 – Introduction to Molecular Biology</td>
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<tr>
<td>Electrical Engineering 110 – Circuit Analysis II</td>
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<td>Pathway Course (Electrical Engineering 132A – Introduction to Communication Systems) †</td>
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<td>Electrical Engineering 115A – Analog Electronic Circuits I</td>
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<td>Electrical Engineering 115AL – Analog Electronics Laboratory I</td>
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<td>Mathematics 132 – Complex Analysis for Applications</td>
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<tr>
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**Senior Year**

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<td>Electrical Engineering 101 – Engineering Electromagnetics</td>
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<td>Statistics 105 – Statistics for Engineers</td>
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<td>Pathway Course (Electrical Engineering 141 – Principles of Feedback Control) †</td>
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<td>Breadth Course*</td>
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<td>Pathway Course (Electrical Engineering 176 – Lasers in Biomedical Applications or Mechanical and Aerospace Engineering 105A – Introduction to Engineering Thermodynamics) †</td>
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<tr>
<td>Pathway Design Course*</td>
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</table>

**TOTAL**

188

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).

†See page 73 for the biomedical engineering pathway.
# B.S. in Electrical Engineering
## Computer Engineering Option Curriculum

### Freshman Year

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<th>1st Quarter</th>
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<td>Computer Science 33 – Introduction to Computer Organization</td>
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<td>Electrical Engineering 3 – Introduction to Electrical Engineering</td>
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<td>Mathematics 32A – Calculus of Several Variables</td>
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### Sophomore Year

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<tbody>
<tr>
<td>Electrical Engineering 2 – Physics for Electrical Engineers</td>
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<td>Electrical Engineering 103 – Applied Numerical Computing</td>
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### Junior Year

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<td>Electrical Engineering 102 – Systems and Signals</td>
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<td>Electrical Engineering 110 – Circuit Analysis II</td>
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<tr>
<td>Electrical Engineering 110L – Circuit Measurements Laboratory</td>
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<td>Electrical Engineering 113 – Digital Signal Processing</td>
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<td>Electrical Engineering 115A – Analog Electronic Circuits I</td>
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<td>Electrical Engineering 131A – Probability</td>
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### Senior Year

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<td>Electrical Engineering M116C or Computer Science M151B – Computer Systems Architecture</td>
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<tr>
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<td>Pathway Course (Computer Science 131 – Programming Languages or 132 – Compiler Construction or 180 – Introduction to Algorithms and Complexity)</td>
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<td>Pathway Design Course†</td>
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</table>

**Total**: 188

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†See page 73 for the computer engineering pathway.
# B.S. in Materials Engineering Curriculum

## FRESHMAN YEAR

<table>
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<tr>
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<th>Course</th>
<th>Units</th>
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<td>English Composition 3 – English Composition, Rhetoric, and Language</td>
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<td>Materials Science and Engineering 10 – Freshman Seminar: New Materials</td>
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<td>Mathematics 31A – Differential and Integral Calculus</td>
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<td>Physics 1A – Mechanics</td>
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<td>Physics 1B – Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<td>Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Computer Science 31 – Introduction to Computer Science I</td>
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<td>Civil and Environmental Engineering 101 (Statics and Dynamics) or Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 90L – Physical Measurement in Materials Engineering</td>
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<td>Mathematics 33B – Differential Equations</td>
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## JUNIOR YEAR

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<tr>
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<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 110/110L – Introduction to Materials Characterization A/Laboratory</td>
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<td>Materials Science and Engineering 130 – Phase Relations in Solids</td>
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<td>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>3rd</td>
<td>Materials Science and Engineering 132 – Structure and Properties of Metallic Alloys</td>
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<td>Elective†</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>HSSEAS GE Elective*</td>
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<tr>
<td></td>
<td>Materials Engineering Elective†</td>
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<tr>
<td>3rd</td>
<td>Materials Engineering Laboratory Course†</td>
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<td></td>
<td>Materials Science and Engineering 140 – Materials Selection and Engineering Design</td>
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<td>Breadth Course*</td>
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**TOTAL** 185, 186, or 187

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
†See counselor in 6426 Boelter Hall for details.
# B.S. in Materials Engineering

## Electronic Materials Option 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>Computer Science 31 – Introduction to Computer Science I</td>
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<tr>
<td>Materials Science and Engineering 10 – Freshman Seminar: New Materials</td>
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<tr>
<td>Mathematics 31A – Differential and Integral Calculus</td>
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<tr>
<td>Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td>Mathematics 31B – Integration and Infinite Series</td>
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<td>Physics 1A – Mechanics</td>
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<td><strong>3rd Quarter</strong></td>
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<td>English Composition 3 – English Composition, Rhetoric, and Language</td>
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<tr>
<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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<thead>
<tr>
<th>SOPHOMORE YEAR</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Materials Science and Engineering 104 – Science of Engineering Materials</td>
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<td>Mathematics 32B – Calculus of Several Variables</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Mathematics 33A – Linear Algebra and Applications</td>
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<tr>
<td>Physics 1C (Electrodynamics, Optics, and Special Relativity) or Electrical Engineering 1 (Electrical Engineering Physics I)</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Materials Science and Engineering 90L – Physical Measurement in Materials Engineering</td>
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<tr>
<td>Mathematics 33B – Differential Equations</td>
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<tr>
<td>Mechanical and Aerospace Engineering 101 – Statics and Strength of Materials</td>
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<tr>
<td>HSSEAS GE Elective*</td>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Electrical Engineering 10 – Circuit Analysis I</td>
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<tr>
<td>Materials Science and Engineering 110/110L – Introduction to Materials Characterization A/Laboratory</td>
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<td>Materials Science and Engineering 130 – Phase Relations in Solids</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Electrical Engineering 101 – Engineering Electromagnetics</td>
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<tr>
<td>Materials Science and Engineering 120 (Physics of Materials) or Electrical Engineering 2 (Physics for Electrical Engineers)</td>
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<tr>
<td>Materials Science and Engineering 122 – Principles of Electronic Materials Processing</td>
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<td>Breadth Course*</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Electrical Engineering 121B – Principles of Semiconductor Device Design</td>
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<tr>
<td>Materials Science and Engineering 121/121L – Materials Science of Semiconductors/Laboratory</td>
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<tr>
<td>Electronic Materials Elective†</td>
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<tr>
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<td>Upper Division Mathematics Elective†</td>
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<tr>
<td>Materials Science and Engineering 131/131L – Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>Electronic Materials Laboratory Course†</td>
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<td>Materials Science and Engineering 140 – Materials Selection and Engineering Design</td>
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**TOTAL** 187, 188, or 189

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
†See counselor in 6426 Boelter Hall for details.
## B.S. in Mechanical Engineering Curriculum

### FRESHMAN YEAR

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<tr>
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<th>Course</th>
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<td><strong>Chemistry and Biochemistry 20A – Chemical Structure</strong></td>
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<td><strong>Mathematics 31A – Differential and Integral Calculus</strong></td>
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<td>2nd Quarter</td>
<td><strong>Chemistry and Biochemistry 20B/20L – Chemical Energetics and Change</strong></td>
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<td><strong>Mathematics 31B – Integration and Infinite Series</strong></td>
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<td><strong>Physics 1A – Mechanics</strong></td>
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<td><strong>Mathematics 32A – Calculus of Several Variables</strong></td>
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<td><strong>Physics 1B – Oscillations, Waves, Electric and Magnetic Fields</strong></td>
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### SOPHOMORE YEAR

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<td><strong>Mathematics 33A – Linear Algebra and Applications</strong></td>
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<td><strong>Computer Science 31 – Introduction to Computer Science I</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 107/107L – Introduction to Modeling and Analysis of Dynamic Systems/Laboratory</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 102 – Dynamics of Particles and Rigid Bodies</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 105D – Transport Phenomena</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 171A – Introduction to Feedback and Control Systems</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 183 – Introduction to Manufacturing Processes</strong></td>
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### SENIOR YEAR

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<td>1st Quarter</td>
<td><strong>Electrical Engineering 110L – Circuit Measurements Laboratory</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 162A – Introduction to Mechanisms and Mechanical Systems</strong></td>
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<td><strong>Mechanical Engineering Elective</strong></td>
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<td><strong>Mechanical and Aerospace Engineering 162B – Mechanical Product Design</strong></td>
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*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of breadth and HSSEAS GE (see page 21 for details).
Correspondence Directory

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

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http://www.intl.ucla.edu

Financial Aid Office, A129J Murphy Hall
http://www.fao.ucla.edu

Graduate Admissions Office, 1255 Murphy Hall
http://www.gdnet.ucla.edu

Housing: Community Housing Office, 360 De Neve Drive
http://www.cho.ucla.edu
UCLA Housing Service, 360 De Neve Drive
http://www.housing.ucla.edu/myhousing/

Office of the President, Admissions
http://www.universityofcalifornia.edu/admissions/welcome.html

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

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

Undergraduate Admissions and Relations with Schools, 1147 Murphy Hall
http://www.admissions.ucla.edu

Henry Samueli School of Engineering and Applied Science
http://www.engineer.ucla.edu

Office of Academic and Student Affairs, 6426 Boelter Hall
http://www.seasoasa.ucla.edu

Bioengineering Department, 7523 Boelter Hall
http://www.bioeng.ucla.edu

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

Chemical and Biomolecular Engineering Department, 5531 Boelter Hall
http://www.chemeng.ucla.edu

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

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

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

Materials Science and Engineering Department, 6532 Boelter Hall
http://www.seas.ucla.edu/ms/

Mechanical and Aerospace Engineering Department, 48-121 Engineering IV
http://www.mae.ucla.edu

Continuing Education in Engineering, 542 UNEX
http://www.uclaextension.edu

Engineering and Science Career Services, UCLA Career Center, 501 Westwood Plaza, Strathmore Building
http://career.ucla.edu

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Bioengineering, Mi Suk Kwon, (310) 825-0968, misuk@ea.ucla.edu

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Materials Engineering, Chauncey Isom, (310) 206-2891, chauncey@ea.ucla.edu; Jan J. LaBuda (310) 825-2514, jan@ea.ucla.edu

Mechanical Engineering, Matt Dingman, (310) 825-1704, dingman@ea.ucla.edu; Chauncey Isom, (310) 206-2891, chauncey@ea.ucla.edu
A
Academic Residence Requirement, 21
Active Materials Laboratory, 100
Admission to the School
As a Freshman, 18
As a Graduate Student, 25
As a Transfer Student, 18
Admission to the School, 18
Advanced Placement Tests, Credit for, 18
Advanced Soil Mechanics Laboratory, 49
Advising, 23
Arthur Ashe Student Health and Wellness Center, 10
Artificial Intelligence Laboratory, 61
Autonomous Vehicle Systems Instrumentation Laboratory, 100

B
Bachelor of Science Degrees, Requirements for, 21
Biocybernetics Laboratory, 62
Bioengineering Department, 26
Bachelor of Science Degree, 26
Course Descriptions, 27
Faculty Areas of Thesis Guidance, 27
Graduate Study, 27
Biomedical Engineering Interdepartmental Program, 28
Course Descriptions, 32
Fields of Study, 29
Graduate Study, 29
Biomedical Engineering Laboratory, 62
Biomedical Engineering Laboratories, 39
Building Earthquake Instrumentation Network, 49

C
Career Services, 9
Center for Embedded Networking Sensing, 111
Center for Excellence in Engineering and Diversity, 13
Center for High-Frequency Electronics, 79
Center for Information and Computation Security (CICS), 62
Center for Information and Computation Security, 62
Center for Nanoscience Innovation for Defense, 111
Center for Scalable and Integrated Nanomanufacturing, 111
Ceramic Processing Laboratory, 92
CEWS Systems Laboratory, 62

Data Mining Laboratory, 63

B.S., 21
Engineer, 24
Master of Engineering, 24
Master of Science in Engineering (online), 24
Master of Science, 24
Ph.D., 24
Department Requirements, 22

Departmental Scholar Program, 15
Digital Arithmetic and Reconfigurable Architecture Laboratory, 62
Distributed Simulation Laboratory, 63

Electrical Engineering Department, 72
Bachelor of Science Degree, 73
Course Descriptions, 82
Facilities and Programs, 79
Fields of Study, 77
Graduate Study, 74
Electrochemistry Laboratory, 60
Electromagnetics Laboratories, 80
Electron Microscopy Laboratories, 92
Electronic Materials Processing Laboratory, 40
Embedded and Reconfigurable System Design Laboratory, 63
Endowed Chairs, 6
Environmental Engineering Laboratories, 49
Experimental Fracture Mechanics Laboratory, 49
Experimental Mechanics Laboratory, 49

Fees and Financial Support, 10
Graduate Students, 12
Undergraduate Students, 11
Fellowships, 12
Flight Systems Research Center, 111
Fluid Mechanics Research Laboratory, 100

Functional Engineered Nano Architectonics Focus Center, 112
Fusion Technology Center, 100

General Education Requirements, 21
Glass and Ceramics Research Laboratories, 92
Grade Disputes, 16
Grants, 11

Harassment, 16
Heat Transfer Laboratories, 100
High-Performance Internet Laboratory, 62
Honors, 23
Dean’s Honors List, 23
Latin Honors, 23
Human/Computer Interface Laboratory, 62
I
Institute for Cell Mimetic Space Exploration, 112
Institute of Plasma and Fusion Research, 112
Instructional Computer Facility, 9
Internet Research Laboratory, 62

K
Knowledge-Based Multimedia Medical Distributed Database Systems Laboratory, 63

L
Laboratory for Advanced System Research, 63
Large-Scale Structure Test Facility, 49
Library Facilities, 9
Science and Engineering Library, 9
University Library System, 9
Living Accommodations, 10
Loans, 11

M
Materials and Plasma Chemistry Laboratory, 40
Materials Degradation Characterization Laboratory, 100
Materials Science and Engineering Department, 89
Bachelor of Science Degree, 90
Course Descriptions, 93
Facilities, 92
Faculty Areas of Thesis Guidance, 92
Fields of Study, 92
Graduate Study, 91
Mechanical and Aerospace Engineering Department, 96
Bachelor of Science Degrees, 96
Course Descriptions, 102
Facilities, 100
Faculty Areas of Thesis Guidance, 101
Fields of Study, 99
Graduate Study, 97
Mechanical Testing Laboratory, 92
Mechanical Vibrations Laboratory, 49
Metallographic Sample Preparation Laboratory, 92
Micro-Manufacturing Laboratory, 100
Microsciences Laboratory, 101
Modeling Animation and Graphics Laboratory, 62
Multifunctional Composites Laboratory, 101
Multimedia Stream System Laboratory, 63
Multimedia Systems Laboratory, 63

N
Nanoelectronics Research Facility, 80
Nanomaterials Laboratory, 92
Nanoparticle Technology and Air Quality Engineering Laboratory, 40
Nanoscale Heat Transfer and Thermoelectrics Laboratory, 101
Nondestructive Testing Laboratory, 92
Nondiscrimination, 16

O
Official publications, 15
Optical Metrology Laboratory, 49
Organic Electronic Materials Processing Laboratory, 92

P
Parallel Computing Laboratory, 63
Photonics and Optoelectronics Laboratories, 80
Plasma and Beam Assisted Manufacturing Laboratory, 101
Plasma Electronics Facilities, 80
Polymer and Separations Research Laboratory, 41
Precollage Outreach Programs, 13
Prizes and awards, 15
Process Systems Engineering Laboratory, 41

R
Reinforced Concrete Laboratory, 49

S
Scholarship Requirement, 21
Scholarships, 11
School Requirements, 21
Schoolwide Programs, Courses, and Faculty, 109
Course Descriptions, 109
Faculty Areas of Thesis Guidance, 109
Semiconductor and Optical Characterization Laboratory, 92
Services for Students with Disabilities, 10
Shop Services Center, 9
Software Systems Laboratory, 63
Soil Mechanics Laboratory, 49, 50
Solid-State Electronics Facilities, 80
Special Programs, Activities, and Awards, 13
Structural Design and Testing Laboratory, 49
Student and Honorary Societies, 15
Student Organizations, 14
Study List, 23
Subsonic Wind Tunnel, 101

T
Teaching Assistantships, 12
Theory Laboratory, 62
Thin Film Deposition Laboratory, 92
Thin Films, Interfaces, Composites, Characterization Laboratory, 101

U
Unit Requirement, 21
University Requirements, 21

V
Vision Laboratory, UCLA, 62
VLSI CAD Laboratory, 63

W
Web Information Systems Laboratory, UCLA, 63
Western Institute of Nanoelectronics, 112
Wireless Adaptive Mobility Laboratory, 62
Women in Engineering, 15
Work-Study Programs, 12

X
X-Ray Diffraction Laboratory, 92
X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility, 92