Screen snapshot of the new engineering building from a real-time visual simulation model of the UCLA campus.
# Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2004</th>
<th>Winter 2005</th>
<th>Spring 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>First day for continuing students to check URSA at <a href="http://www.ursa.ucla.edu">http://www.ursa.ucla.edu</a> for assigned enrollment appointments</td>
<td>June 16, 2004</td>
<td>November 3, 2004</td>
<td>February 9, 2005</td>
</tr>
<tr>
<td>URSA enrollment appointments begin</td>
<td>June 28</td>
<td>November 17</td>
<td>February 22</td>
</tr>
<tr>
<td>Late registration fee payment in person with $50 late fee</td>
<td>September 21</td>
<td>December 21</td>
<td>March 21</td>
</tr>
<tr>
<td>QUARTER BEGINS</td>
<td>September 27</td>
<td>January 3, 2005</td>
<td>March 30</td>
</tr>
<tr>
<td>Instruction begins</td>
<td>September 30</td>
<td>January 6</td>
<td>April 4</td>
</tr>
<tr>
<td>Last day for undergraduates to ADD courses with PTE number with $3 per course fee through URSA</td>
<td>October 22</td>
<td>January 28</td>
<td>April 22</td>
</tr>
<tr>
<td>Last day for undergraduates to DROP nonimpacted courses (without transcript notation) with $3 per transaction fee through URSA</td>
<td>October 29</td>
<td>February 4</td>
<td>April 29</td>
</tr>
<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP) with $3 per transaction fee through URSA</td>
<td>November 12</td>
<td>February 18</td>
<td>May 13</td>
</tr>
<tr>
<td>Instruction ends</td>
<td>December 10</td>
<td>March 16</td>
<td>June 10</td>
</tr>
<tr>
<td>Review day</td>
<td></td>
<td>March 17</td>
<td></td>
</tr>
<tr>
<td>Final examinations begin</td>
<td></td>
<td>March 18</td>
<td></td>
</tr>
<tr>
<td>Final examinations</td>
<td>December 13-17</td>
<td>March 21-24</td>
<td>June 13-17</td>
</tr>
<tr>
<td>QUARTER ENDS</td>
<td>December 17</td>
<td>March 24</td>
<td>June 17</td>
</tr>
<tr>
<td>HSSEAS Commencement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic and administrative holidays</td>
<td>November 11</td>
<td>January 17</td>
<td>May 30</td>
</tr>
<tr>
<td></td>
<td>November 25-26</td>
<td>February 21</td>
<td></td>
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<tr>
<td></td>
<td>December 24, 27</td>
<td>March 25</td>
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<tr>
<td></td>
<td>December 30-31</td>
<td></td>
<td></td>
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</tbody>
</table>

# Admission Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2004</th>
<th>Winter 2005</th>
<th>Spring 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filing period for undergraduate applications (file with UC Undergraduate Application Processing Service, P.O. Box 23460, Oakland, CA 94623-0460)</td>
<td>November 1-30, 2003</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Last day to file application for graduate admission or readmission with complete credentials and application fee, with Graduate Admissions/Student and Academic Affairs, 1255 Murphy Hall, UCLA, Los Angeles, CA 90024-1428</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
</tr>
<tr>
<td>Reentering students eligible to enroll should begin to receive URSA notification letter at mailing address</td>
<td>June 18, 2004</td>
<td>November 8</td>
<td>February 11</td>
</tr>
<tr>
<td>Last day to file Undergraduate Application for Readmission form at 1113 Murphy Hall (late applicants will pay a $50 late payment fee)</td>
<td>August 16</td>
<td>November 29</td>
<td>February 25</td>
</tr>
</tbody>
</table>
A Message from the Dean

Since it first opened its doors to students in 1945, the UCLA Henry Samueli School of Engineering and Applied Science has consistently been at the forefront of cutting-edge, interdisciplinary research. Among other notable accomplishments, UCLA is home to the first node of the Internet and the first reverse-osmosis membrane.

We are engaged in a relentless pursuit of high-quality education and research in new frontiers of applied science and engineering, with demonstrated preeminence in such multidisciplinary areas as information technology, bioengineering, nanomanufacturing, national infrastructure renewal, and the protection of our environment and natural resources.

Located next to the world-renowned UCLA Medical Center, and home to many cutting-edge research centers, the School of Engineering is ideally situated for interdisciplinary research and education. UCLA also benefits from its proximity to the Los Angeles entertainment and media industries, Silicon Valley, the defense and aerospace industries, and a growing biotechnology sector.

To prepare our students for the fast-paced changes occurring in the engineering profession, we are focusing on curriculum reforms that ensure our graduates receive an education with the breadth and depth they need to succeed. We are broadening the curriculum and are considering a three-course minor in a discipline different from the students' major. In addition, our recently established Bioengineering Department welcomes its first freshman class in Fall Quarter 2004. Undergraduate student research opportunities are widely available and we encourage our students to take advantage of them.

Our distinguished faculty is composed of recognized experts in their fields, including 15 members of the National Academy of Engineering. Many faculty members are award-winning educators; and every faculty member, no matter how senior, teaches at least one undergraduate course each year.

The School has several world-class interdisciplinary research centers including the Center for Embedded Networked Sensing (CENS), the Institute for Cell Mimetic Space Exploration (CMISE), the Center for Scalable and Integrated Nanomanufacturing (SINAM), the Functional Engineered Nano-Architectonics Focus Center (FENA), and the Center for Nano-science Innovation for Defense (CNID). Our School is also an active participant in the California NanoSystems Institute (CNSI), located at UCLA. These centers offer ample opportunities for undergraduate students to participate in research.

We are seeking exceptional and dedicated students who want to contribute to the community, to engineering, and to industry. I invite you to consider becoming a UCLA engineer.

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

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
Milos D. Ercegovac, Ph.D., Professor and Chair, Computer Science Department
Mark Goorsky, Ph.D., Professor and Chair, Materials Science and Engineering Department
H. Thomas Hahn, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Vasilios I. Manousiouthakis, Ph.D., Professor and Chair, Chemical Engineering Department
Carlo D. Montemagno, Ph.D., Professor and Chair, Bioengineering Department
Yahya Rahmat-Samii, 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 boasts broad vistas, landscaped gardens, and a blend of architectural styles ranging from Romanesque to modern. Campus moods vary from the activity of Bruin Walk to the serenity of the Japanese Garden.

UCLA is recognized as the West’s leading center for the arts, culture, and medical research. Each year, more than half a million people attend visual and performing arts programs on campus, while more than 300,000 patients from around the world come to the UCLA Medical Center for treatment. The university has roughly 290 buildings on 419 acres that house the College of Letters and Science and 11 professional schools serving over 37,000 students. One in every 140 Californians holds a UCLA degree.

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

Today, UCLA is rated one of the best public research universities in the U.S. and among a handful of top U.S. research universities, public and private.

The top administrative officer is Chancellor Albert Carnesale, the eighth chief executive in UCLA’s 65-year history.

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

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

Current research programs focus on such areas as biomedical informatics, the twenty-first-century Internet, nano and microelectromechanical (MEMS) systems, nanomanufacturing and nanotechnologies, wireless technologies, smart materials, earthquake engineering, neuroengineering, metabolic engineering, information technologies, and alternative energy solutions.

HSSEAS offers 28 academic and professional degree programs, including an interdepartmental graduate degree program in biomedical engineering. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering. The undergraduate curricula leading to these degrees provide students with a firm foundation in engineering and applied science and prepare graduates for immediate practice of the profession as well as advanced studies. In addition to engineering courses, students complete about one year of study in the humanities, social sciences, and/or fine arts.

Master of Science and Ph.D. degrees are offered in Aerospace Engineering, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Manufacturing Engineering (M.S. only), Materials Science and Engineering, and Mechanical Engineering. The Master of Engineering degree may be earned through the Engineering Executive Program. The Engineer degree is a more advanced degree than the M.S. but does not require the research effort and orientation involved in a Ph.D. dissertation. For information on the Engineer degree, see Graduate Programs on page 23. A one-
The Engineering Profession

Endowed Chairs

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

- L.M.K. Boelter Chair in Engineering
- Evalyn C. Knight Chair in Engineering
- Roy and Carol Doumani Chair in Biomedical Engineering
- Norman E. Friedmann Chair in Knowledge Sciences
- Levi James Knight, Jr., Chair in Engineering
- Nippon Sheet Glass Company Chair in Materials Science
- Northrop Grumman Chair in Electrical Engineering
- Northrop Grumman Chair in Electrical Engineering/ Electromagnetics
- Northrop Grumman Opto-Electronic Chair in Electrical Engineering
- Ralph M. Parsons Chair in Chemical Engineering
- Jonathan B. Postel Chair in Computer Systems
- Jonathan B. Postel Chair in Networking
- Raytheon Company Chair in Electrical Engineering
- Raytheon Company Chair in Manufacturing Engineering
- Ben Rich Lockheed Martin Chair in Aeronautics
- Rockwell International Chair in Engineering
- William Frederick Seyer Term Chair in Materials Electrochemistry

The Engineering Profession

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

Aerospace Engineering

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

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

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

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

Bioengineering

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

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

Chemical Engineering

Chemical engineers use their knowledge of mathematics, physics, chemistry, and biology to meet the needs of our technological society. They design, research, develop, operate, and manage the chemical and petroleum industries and are leaders in the fields of hazardous wastes control, environmental protection, biotechnology and biomedical engineering, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, food, paper, aerospace, automotive, and semiconductor industries. Architectural, engineering, and construction firms employ chemical engineers for equipment and process design. It is also their mission to develop the clean and...
environmentally friendly technologies of the future.

Major areas of fundamental interest within chemical engineering are

1. **Applied chemical kinetics**, which includes the design of chemical processes and reactors and combustion systems,

2. **Transport phenomena**, which involves the exchange of momentum, heat, and mass across interfaces and has applications to the separation of valuable materials from mixtures, or of pollutants from gas and liquid streams,

3. **Thermodynamics**, which is fundamental to both separation processes and chemical reactor design,

4. **Plant and process design**, synthesis, optimization, simulation, and control, which provides the overall framework for integrating chemical engineering knowledge into industrial application and practice.

**Civil and Environmental Engineering**

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

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

**Computer Science and Engineering**

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

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

**Electrical Engineering**

There are several fields of specialization, both theoretical and applied, within the electrical engineering discipline. The Electrical Engineering Department provides study and training in the areas of communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization/operations research, integrated circuits and systems, microelectromechanical systems/nanotechnology (MEMS/nano), photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. A brief description of each area is provided under Fields of Study on page 69. Each of the fields presents opportunities for employment to the electrical engineering graduate.

**Manufacturing Engineering**

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

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

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

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

**Materials Engineering**

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

Two programs within materials engineering are available at UCLA:

1. In the **materials engineering** program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries. Materials engineers are responsible for the selection and testing of materials for specific applications. Traditional fields of metallurgy and ceramics have been merged in industry, and this program reflects the change.

2. In the **electronic materials option** of the materials engineering program, students learn the basics of materials engineering with a concentration in electronic materials and processing. The optional program requires additional coursework which includes five to eight electrical engineering courses.

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

**Mechanical Engineering**

Mechanical engineering is a broad discipline finding application in virtually all industries and manufactured products. The mechanical engineer applies principles of mechanics, dynamics, and energy transfer to the design, analysis, testing,
and manufacture of consumer and industrial products. A mechanical engineer usually has specialized knowledge in areas such as design, materials, fluid dynamics, solid dynamics, heat transfer, thermodynamics, dynamics, control systems, manufacturing methods, and human factors. Applications of mechanical engineering include design of machines used in the manufacturing and processing industries, mechanical components of electronic and data processing equipment, engines and power-generating equipment, components and vehicles for land, sea, air, and space, and artificial components for the human body. Mechanical engineers are employed throughout the engineering community as individual consultants in small firms providing specialized products or services, as designers and managers in large corporations, and as public officials in government agencies.

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

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

The B.S. program in Mechanical Engineering at UCLA provides excellent preparation for a career in mechanical engineering and a foundation for advanced graduate studies. Graduate studies in one of the specialized fields of mechanical engineering prepare students for a career at the forefront of technology.
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), and offices of faculty and administration. The SEL/Engineering and Mathematical Sciences Library is also in Boelter Hall. Additional faculty offices and laboratories, the Shop Services Center, and the Student and Faculty Shop are in the Engineering I building.

Library Facilities

University Library System

The UCLA Library, a campuswide network of libraries serving programs of study and research in many fields, is among the top 10 ranked research libraries in the U.S. Total collections number more than 7.6 million volumes, and more than 79,000 serial titles are received regularly. Some 15,000 serials and databases are electronically available, and the UCLA Library Catalog is linked to the library's homepage at http://www.library.ucla.edu.

Science and Engineering Library

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

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

The SEL collection contains over 568,000 volumes, subscriptions to almost 6,000 current serials, and over 4,000,000 technical reports. Ask a Librarian online, e-mail, and in-person reference assistance is provided weekdays.

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 science resources, are featured on the SEL website. See http://www.library.ucla.edu/sel/.

Services

Instructional Computer Facility

HSSEAS maintains a network of 10 Sun Fire 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. Five 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 109 annual offerings draws participants from around the world for two- to five-day intensive programs. The acclaimed Technical Management Program holds its sixty-eighth offering in September 2004 and sixty-ninth in March 2005.

The Information Systems program offers 229 classes annually, including six certificate programs and four sequential programs in evening, day, weekend, and online formats covers a broad range of information technologies.

Each year, the department offers 124 classes in engineering disciplines that include manufacturing engineering, electrical engineering, astronautical engineering, construction management, and PE review classes. In addition, 85 technical management offerings complement the engineering offerings. Most engineering and technical management classes are in a quarter-length, evening format. Call (310) 825-3344 for short course programs, (310) 825-3858 for the Technical Management Program, (310) 825-4100 for information systems programs, and (310) 206-1548 for engineering or technical management classes, or fax (310) 206-2815. See http://www.uclaextension.edu.
Career Services

Engineering and Science Career Services
Engineering and Science Career Services, a branch of the UCLA Career Center, assists HSSEAS undergraduate and graduate students and alumni explore career possibilities, prepare for graduate and professional school, obtain employment and internship leads, and develop skills for conducting a successful job search.

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

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

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

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

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

Services for Students with Disabilities
The Office for Students with Disabilities (OSD), A255 Murphy Hall (voice 310-825-1501, TTY 310-206-6083, fax 310-825-9656, http://www.sanet.ucla.edu/osd/), provides academic support services to regularly enrolled students with documented permanent or temporary disabilities in compliance with Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act of 1990, and University policies. Academic support services are determined for each student based on specific disability-based requirements. Services include readers, note takers, sign language interpreters, Learning Disabilities Program, special parking, registration assistance, fee deferrals, and enrollment in the Disabilities and Computing Program. There is no fee for any of these services, and all contacts and assistance are handled confidentially.

Fees and Financial Support

Fees and Expenses
The 2004-05 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.

<table>
<thead>
<tr>
<th>2004-05 ANNUAL UCLA GRADUATE AND UNDERGRADUATE FEES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fees are subject to revision without notice</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>University registration fee</td>
</tr>
<tr>
<td>Graduate Students</td>
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<td>Nonresident $23,541.52</td>
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Financial Aid
Office, A129J Murphy Hall, (310) 206-951381, Los Angeles, CA 90095-1495, (310) 825-4491, http://www.cho.ucla.edu, provides information and current listings for University-owned apartments, cooperatives, private apartments, roommates, rooms in private homes, room and board in exchange for work, and short-term housing. A current BruinCard or a letter of acceptance and valid photo identification card are required for service.

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

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

Financial Aid

Undergraduate Students
Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. Applications for each academic year are available in January. The priority application deadline for financial aid for the 2005-06 academic year is March 2, 2005. 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.


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

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

The following scholarships are available only to HSSEAS undergraduates:

- Altera Scholarship: For computer science, computer science and engineering, and electrical engineering students; four $4,750 scholarships
- Andersen Consulting Outstanding Junior Award in memory of Kalpesh Vardhan: For an outstanding junior engineering student; one-year $2,000 award
- ARCO Products Company Scholarship: For students in chemical engineering
- Eugene Birnbaum Scholarship: For sophomores engineering students with interest in research
- Stanley Black Scholarship sponsored by the Jewish Community Foundation: For an engineering student with high academic achievement
- L.M.K. Boelter Scholarship Fund: For students in the field of engineering
- Chevron U.S.A., Inc., Scholarship: For students in chemical engineering
- Charles Martin Duke, Jr., Scholarship in Structural Engineering: For a junior in the field of structural engineering
- Engineering Senior Gift: For a sophomore or junior HSSEAS student who has completed at least two quarters at UCLA and is involved in student organizations, programs, projects, or community service
- General Motors Scholarship: For aerospace, mechanical, or electrical engineering majors
- Audrey and James Gilstrap Scholarship: For engineering students
- W. Brandt Goldworthy Scholarship: For students studying composite materials in the Department of Materials Science and Engineering
- Haller Scholarship: Field of electrical engineering: to provide significant assistance, primarily for students 25 years old or over
- William J. Knapp Scholarship in Ceramics: For a junior or senior in materials engineering for achievement in studies related to ceramics
- Michael J. Kuhlmian Memorial Scholarship: For a junior or senior in the electrical engineering field
- Paul H. Lane Perpetual Engineering Scholarship: For juniors or seniors (U.S. citizens or permanent residents) in the field of civil (nontransportation), electrical (power option), or mechanical (nonaerospace) engineering; sponsored by the Los Angeles City Department of Water and Power
- Lear Siegler Scholarship: For a junior or senior (must be U.S. citizen) selected by priority from aerospace engineering, electrical engineering, mechanical engineering (CAD/CAM emphasis), computer science and engineering
- Maxim Scholarship: For a student from northern California in electrical engineering; four-year award
- Joseph W. McCutchan Memorial Scholarship Fund: Field of engineering
- Richard B. Nelson Memorial Scholarship Fund: For civil engineering students with an interest in structures
- Rhone-Poulenc Contribution to Excellence Scholarship: For a junior or senior in the field of chemical engineering
- Dick and Pat Stern Scholarship: For an engineering student with high academic achievement
- Texaco Scholarship: For chemical, civil, and mechanical engineering majors with interest in the petroleum industry
- For more scholarship information, see http://seasoasa.ucla.edu/fee.html

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

Federal Pell Grants are federal aid awards designed to provide financial assistance to those who need funds to attend post-high school educational institutions. Undergraduate students who are
U.S. citizens or eligible noncitizens are required by the University to apply. Detailed information on other grants for students with demonstrated need is available from the Financial Aid Office, A129J Murphy Hall, (310) 206-0400.

**Federal Family Education Loan Program**

**Federal loans** are available to undergraduate or graduate students who are U.S. citizens or eligible noncitizens and who are carrying at least a half-time academic workload. Information on loan programs is available from the Financial Aid Office, A129J Murphy Hall.

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

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

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

**Work-Study Programs**

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

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

Students must be enrolled full-time (12 units for undergraduates, 8 for graduate students) and not be appointed at more than 50 percent time while employed at UCLA. Students not carrying the required units or who exceed 50 percent time employment are subject to Social Security or Medicare taxation.

**Graduate Students**

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 (354 positions).
2. Employment as a teaching assistant (about 494 positions).
3. Employment as a graduate student researcher (about 1824 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 $14,357* to $16,833*, 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.

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*Nine-month 2003-04 salaries

Eleven-month 2003-04 salaries

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2005-06 competition. Applicants should check the deadline for submitting the UCLA Application for Graduate Admission and the Fellowship Application for Entering Graduate Students with their preferred department.

**Need-Based Aid**

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

Need-based awards are administered by the Financial Aid Office in A129J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid. Continuing graduate students should contact the Financial Aid Office in November 2004 for information on 2005-06 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 Engineering; supports study in chemical engineering
- **William and Mary Beedle Fellowship.** Department of Chemical Engineering; supports study in chemical engineering
- **John J. and Clara C. Boelter Fellowship.** Supports study in engineering
- **Leon and Alyne Camp Fellowship.** Department of Mechanical and Aerospace Engineering; supports study in engineering; must be U.S. citizen
- **Deutsch Company Fellowship.** Supports engineering research on projects that aid small business in Southern California
- **GTE Fellowship.** Departments of Computer Science and Electrical Engineering; supports study in computer science and electrical engineering
- **IBM Doctoral Fellowship.** Supports doctoral study in computer science
- **Les Knesel Scholarship Fund.** Department of Materials Science and Engineering;
supports master’s or doctoral students in ceramic engineering
T.H. Lin Graduate Fellowship. Department of Civil and Environmental Engineering; supports study in the area of structures
Microelectronics Innovation and Computer Research Opportunities (MICRO). Supports students in electrical engineering, computer science, and materials science and engineering with interest in microelectronics who intend to remain in California after graduation; must be U.S. citizen or permanent resident
Microsoft Fellowship. Supports doctoral study in computer science
NCR Fellowship. Department of Computer Science; supports doctoral study in computer science
Martin Rubin Scholarship. Supports two undergraduate or graduate students pursuing a degree in civil engineering with an emphasis in structural engineering
Henry Samueli Fellowship. Department of Electrical Engineering; supports master’s and doctoral students
Semiconductor Research Corporation Fellowship. Department of Electrical Engineering; supports doctoral students in microelectronics; must be U.S. citizen
Sun Microsystems Fellowship. Department of Computer Science; supports incoming graduate students in computer science
Texaco Scholarship. Department of Civil and Environmental Engineering; supports research in the area of environmental engineering
Many other companies in the area also make arrangements for their employees to work part-time and to study at UCLA for advanced degrees in engineering or computer science.

Special Programs, Activities, and Awards

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

Precollege Outreach Programs
Science and Mathematics Achievement and Research Training for Students (SMARTS). A six-week commuter and residential summer program, SMARTS provides a diverse group of 50 to 100 ninth to twelfth graders with rigorous inquiry-based engineering, mathematics, and science enrichment. Tenth and eleventh graders receive an introduction to the scientific process and to laboratory-based investigation through the Research Apprentice Program, sponsored by faculty and graduate research mentors in engineering. Students continue their involvement during the school year by participating in the Saturday Academy Series in Fall and Spring Quarters.
MESA Schools Program (MSP). Through CEED, HSSEAS partners with middle and high school principals to implement MSP services, which focus on outreach and student development in engineering, mathematics, science, and technology. At individual school sites, four mathematics and science teachers serve as MSP advisers and coordinate the activities and instruction for 1,400 students. Advisers work as a team to deliver services that include SAT preparation. MSP prepares students for regional engineering and science competitions and provides an individual academic planning program, academic excellence workshops, CEED undergraduate mentors, field trips, and exposure to high-tech careers. The MSP goal is to increase the numbers of urban and educationally underserved students who are competitively eligible for UC admission, particularly in engineering and computer science.

Students are provided academic planning, SAT preparation, career exploration, and other services starting at the elementary school level through college. HSSEAS/CEED currently serves 18 schools in the Los Angeles Unified School District and seven schools in the Inglewood Unified School District.
Hewlett-Packard Diversity in Education Initiative (HP-DEI). Funded by the Hewlett-Packard Foundation, HP-DEI is a collaboration between CEED and Los Angeles Unified School District-Los Angeles Systematic Initiative to implement mathematics/science reform in 12 urban schools. One component of HP-DEI is the Teacher Training Program, which is designed to deliver high-quality professional development in science, technology, engineering, and mathematics (STEM) subjects for MESA advisers. Forty to sixty MESA teacher advisers participate annually to ensure that their students have the opportunity to learn and advance in rigorous academic programs, and to have increased access to knowledge to ultimately improve student performance.

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

Students join together to solve a math problem at an academic excellence workshop.
CEED Summer Bridge. A two-week intensive residential summer program, CEED Summer Bridge provides advanced preparation and exposure for Fall Quarter classes in mathematics, chemistry, and computer science.

Freshman Orientation Course. Designed to give CEED freshmen exposure to the engineering profession. Engineering 97- Engineering Disciplines also teaches the principles of effective study and team/community-building skills.

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

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

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

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

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

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

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

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

Graduate Programs

OMEGA. The last letter in 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.

American Indian Science and Engineering Society

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

National Society of Black Engineers

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

Society of Latino Engineers and Scientists

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

Women in Engineering
Women make up about 23 percent of the undergraduate and 18 percent of HSSEAS graduate enrollment. Today’s opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a male-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 resume book to help women students find jobs and presents a career day for women high school students. See http://www.seas.ucla.edu/swe/.

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

EGSA Engineering Graduate Students Association
ESUC Engineering Society, University of California. Undergraduate organization that provides a focus for many student activities: sponsors Engineers Week each year and maintains the ESUC lounge in 5800E Boelter Hall
ACM Association for Computing Machinery
AES Audio Engineering Society
AIAA American Institute of Aeronautics and Astronautics
AIChE American Institute of Chemical Engineers
AISES American Indian Science and Engineering Society
ASCE American Society of Civil Engineers
ASME American Society of Mechanical Engineers
BMES Biomedical Engineering Society
Eta Kappa Nu Electrical engineering honor society
EWB Engineers Without Borders
IEEE Institute of Electrical and Electronic Engineers
NSBE National Society of Black Engineers
Phi Sigma Rho Engineering social sorority
PIE Pilipinos in Engineering
SAE Society of Automotive Engineers
SOLES Society of Latino Engineers and Scientists
SWE Society of Women Engineers
Tau Beta Pi Engineering honor society
Triangle Social fraternity of engineers, architects, and scientists

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

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

Russell R. O’Neill Distinguished Service Award is presented annually to an upper division student in good academic standing who has made outstanding contributions through service to the undergraduate student body, student organizations, and the requirements in preparation for the student Welfare program. 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.

Engineering and Applied Science Cooperative Education Program
The Cooperative Education Program is a plan wherein undergraduate students combine periods of regular employment in private industry or government activities (federal, state, county, or city) with alternate periods of study. The work experience becomes a regular, continuing, and essential part of their professional education. This elective plan involves no academic credit for work periods, but students in work periods are encouraged to take such courses as they may be able to arrange, particularly in the Continuing Education Program.
Official Publications

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

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

Grade Disputes

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

The associate dean may form an ad hoc committee to review the complaint. The ad hoc committee members are recommended by the appropriate department chair and the associate dean. The student receives a copy of the ad hoc committee’s report as well as a copy of the associate dean’s recommendation. The student’s file will contain no reference to the dispute. The associate dean informs the students of their rights with respect to complaints and appeals at UCLA.

Nondiscrimination

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

Inquiries regarding the University’s student-related nondiscrimination policies may be directed to the UCLA Campus Counsel, 3149 Murphy Hall, Box 951405, Los Angeles, CA 90095-1405, (310) 825-4042. Speech- and hearing-impaired persons may call TTY (310) 206-6083.

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

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

Harassment

Sexual Harassment

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

Definitions

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

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

b. A student who is also an employee of the University makes submission to or rejection of such conduct a basis for evaluation in making academic or personnel decisions affecting an individ-
The University strives to create an environment that fosters the values of mutual respect and tolerance and is free from discrimination based on race, ethnicity, sex, religion, sexual orientation, disability, age, and other personal characteristics. Certainly, harassment, in its many forms, works against those values and often corrodes a person’s sense of worth and interferes with one’s ability to participate in University programs or activities. While the University is committed to the free exchange of ideas and the full protection of free expression, the University also recognizes that words can be used in such a way that they no longer express an idea, but rather injure and intimidate, thus undermining the ability of individuals to participate in the University community. The University of California Policies Applying to Campus Activities, Organizations, and Students (hereafter referred to as Policies; http://www.ucop.edu/ucophome/umnw/news/acspol/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 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.

Admission

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

Students must submit their applications during the November 1 through 30 filing period. In addition, it is essential that official test scores for the Scholastic Assessment Test (SAT) I or American College Test (ACT) and the SAT II: Subject Tests be received no later than the date in January when the December test scores are normally reported.

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

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

Admission as a Freshman

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 2004 fulfills HSSEAS requirements as indicated on the AP chart.

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

Admission as a Transfer Student

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

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

Required preparation for HSSEAS majors:
1. Mathematics, including calculus I and II, calculus III (multivariable), differential equations, and linear algebra
2. Calculus-based physics courses in mechanics, electricity and magnetism, and waves, sound, heat, optics, and modern physics
3. Chemistry, including two terms of general chemistry. The Computer Science 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 science 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 UCLAs English Composition 3 and a second UC-transferable English composition course

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

Lower Division Courses in Other Departments

Chemistry and Biochemistry 20A, Chemical Structure (4 units)
Chemistry and Biochemistry 20B, Chemical Energetics and Change (4 units)
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></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>
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<td>4 units maximum for both tests</td>
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</tr>
<tr>
<td>Computer Science (A Test)</td>
<td>3, 4, or 5</td>
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<td>Computer Science (AB Test)</td>
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<td>4 excess units</td>
<td>No application</td>
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<tr>
<td>Economics</td>
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<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 or 5</td>
<td>Economics 2 (4 units)</td>
<td>4 units toward social sciences requirement</td>
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<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
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<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 1 (4 units)</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>8 units maximum for both tests</td>
<td>Satisfies Entry-Level Writing Requirement</td>
<td></td>
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<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
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<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
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<tr>
<td>Government and Politics</td>
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<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>Category</td>
<td>Level</td>
<td>Units Required</td>
<td>Extra Units</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>History</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Languages and Literatures</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
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<td></td>
<td>5</td>
<td>French 6 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8</td>
<td></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>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td>Latin</td>
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<td>8 units maximum for both tests</td>
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<tr>
<td>Latin Literature</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
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</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
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<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
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<td></td>
<td>5</td>
<td>Spanish 6 (4 units) plus 4 excess units</td>
<td>4 units toward humanities requirement</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8</td>
<td></td>
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<tr>
<td><strong>Mathematics</strong></td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 units (may be applied toward Mathematics 31A)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Mathematics 31A (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 units (may be applied toward Mathematics 31A and 31B or 31A only)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Mathematics 31A, 31B (8 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Physics</strong></td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, or 5</td>
<td>8</td>
<td></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</td>
<td></td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 units)</td>
<td>4 units toward social sciences requirement</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
Chemistry and Biochemistry 20L. General Chemistry Laboratory (3 units)
English Composition 3, English Composition, Rhetoric, and Language (6 units)
Mathematics 31A. Differential Calculus (4 units)
Mathematics 31B. Integration and Infinite Series (4 units)
Mathematics 32A, 32B. Calculus of Several Variables (4 units each)
Mathematics 33A. Linear Algebra and Applications (4 units)
Mathematics 33B. Differential Equations (4 units)
Physics 1A. Physics for Scientists and Engineers: Mechanics (5 units)
Physics 1B. Physics for Scientists and Engineers: Oscillations, Waves, Electric and Magnetic Fields (5 units)
Physics 1C. Physics for Scientists and Engineers: Electrodynamics, Optics, and Special Relativity (5 units)
Physics 4AL. Physics Laboratory for Scientists and Engineers: Mechanics (2 units)
Physics 4BL. Physics Laboratory for Scientists and Engineers: Electricity and Magnetism (2 units)
The courses in chemistry, mathematics, and physics are those required as preparation for majors in these subjects. Transfer students should select equivalent courses required for engineering or physical sciences majors.

**Requirements for B.S. Degrees**
The Henry Samueli School of Engineering and Applied Science awards B.S. degrees to students who have satisfactorily completed four-year programs in engineering studies.
The curricular requirements for the B.S. degrees in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Computer Science and Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering consist of completing the minimum number of required units (from 181 to 205 units, depending on the curriculum selected), the general University requirements in scholarship, Entry-Level Writing or English as a Second Language (ESL) Requirements, and American History and Institutions Requirement, and the school requirements for scholarship and senior residence. The curricular requirements are described within each department.

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

**School Requirements**

**Scholarship and Minimum Progress**
In addition to the University requirement of at least a C (2.0) grade-point average in all courses taken at any University of California campus, students must achieve at least a 2.0 grade-point average in all upper division University courses offered in satisfaction of the subject and elective requirements of the curriculum. A 2.0 minimum grade-point average in upper division mathematics, upper division core courses, and the major field is also required for graduation.
Full-time HSSEAS undergraduate students must complete a minimum of 36 units in three consecutive terms in which they are registered.

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

**Study Lists and Credit Limitations**
Study Lists require approval of the dean of the school or a designated representative. It is the student's responsibility to present a Study List that reflects satisfactory progress toward the Bachelor of Science degree, according to standards set by the faculty. Study Lists or programs of study that do not comply with these standards may result in enforced withdrawal from the University or other academic action. Undergraduate students in the school are expected to enroll in at least 12 units each term. Students enrolling in less than 12 units must obtain approval by petition to the dean prior to enrollment in courses. The normal program is 16 units per term. Students may not enroll in more than 21 units per term unless an Excess Unit Petition is approved in advance by the dean. Students must attain a minimum grade of C to satisfy the English Composition 3 requirement, which must be met by the end of the second year of enrollment at UCLA (a grade of C—does not satisfy this requirement). Undergraduates who have not taken (or otherwise satisfied the requirement for) English Composition 3 at the time they are admitted must complete the course at UCLA during Fall, Winter, Spring, or Summer Quarter. Students may also complete the equivalent to English Composition 3 at any other UC campus during the Summer Quarter only. After 213 quarter units, enrollment may not normally be continued in the school without special permission from the associate dean. This regulation does not apply to Departmental Scholars.

After students have completed 105 quarter units (regardless of where the units have been completed), they do not receive unit credit or subject credit for courses completed at a community college. Credit earned through the College Level Examination Program (CLEP) may not be applied toward the bachelor's degree.

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

**Curricular Requirements**
Course requirements for the B.S. degrees include the following categories, depending on curriculum selected:
1. Fourteen to 21 engineering major field courses (56 to 84 units), depending on curriculum followed
2. One to 10 engineering core courses (4 to 40 units), depending on curriculum selected
3. Mathematics courses, ranging from 4 to 12 upper division units; see curricula in individual departments
4. HSSEAS general education (GE) requirements: (a) English Composition 3, which must be completed with a minimum grade of C by the end of the second year of enrollment at UCLA; (b) six courses from the humanities and social sciences (eight courses for Computer Science majors), with at least two courses from each category; (c) one life sciences course (two courses for Computer Science majors); this requirement is automatically satisfied for Bioengineering and Chemical Engineering majors and for the biomedical option of the Electrical Engineering major)
All lower division courses taken to satisfy items b and c must be selected from the HSSEAS GE course list at http://www.seasoasa.ucla.edu/ge.html. Students interested in taking a foreign language to satisfy this requirement must first consult with an academic counselor in the Office of Academic and Student Affairs, 6426 Boelter Hall.

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

Computer Science, Computer Science and Engineering, and Electrical Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185, which may be applied toward either the humanities or social sciences section of the GE requirements.

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

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

Advising

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

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

Curricula Planning Procedure

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

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

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

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

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

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

Passed/Not Passed Grading

Students may take one course per term on a Passed/Not Passed basis if they are in good academic standing and are enrolled in at least three and one-half courses (14 units) for the term. Only HSSEAS general education courses (with the exception of English Composition 3 and the ethics course) may be taken on a Passed/Not Passed basis. For more details on P/NP grading, see the Academic Policies section in the UCLA General Catalog or consult the Office of Academic and Student Affairs.

Honors

Dean’s Honors List

Students following the engineering curriculum 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 2004-05 University honors at graduation must have completed 90 or more units for a letter grade at the University of California and must have attained a cumulative grade-point average at graduation which places them in the top five percent of the school (GPA of 3.871 or better) for summa cum laude, the next five percent (GPA of 3.770 or better) for magna cum laude, and the next 10 percent (GPA of 3.643 or better) for cum laude.

Based on grades achieved in upper division courses, engineering students must have a 3.871 grade-point average for summa cum laude, a 3.770 for magna cum laude, and a 3.643 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field courses. To be eligible for an award, students should have completed at least 80 upper division units at the University of California.
Graduate Programs

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

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

Master of Science Degrees

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

Master of Engineering Degree

The Master of Engineering (M.Engr.) degree is granted to graduates of the Engineering Executive Program, a two-year work-study program consisting of graduate-level professional courses in the management of technological enterprises. For details, write to the HSSEAS Office of Academic and Student Affairs, 6426 Boelter Hall, UCLA, Box 951601, Los Angeles, CA 90095-1601, (310) 825-1704.

Engineer Degree

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

Ph.D. Degrees

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

Established Fields of Study for the Ph.D.

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

Biomedical Engineering Interdepartmental Program

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

Chemical Engineering Department

Chemical engineering

Civil and Environmental Engineering Department

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

Computer Science Department

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

Electrical Engineering Department

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

Materials Science and Engineering Department

Ceramics and ceramic processing
Electronic and optical materials
Structural materials

Mechanical and Aerospace Engineering Department

Applied mathematics (established minor field only)
Applied plasma physics and fusion engineering (minor field only)
Dynamics
Fluid mechanics

Fluid mechanics

Fluid mechanics

Fluid mechanics
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.

Graduate Record Examination

Applicants to the HSSEAS graduate programs are required to take the General Test of the Graduate Record Examination (GRE). Applicants for the graduate computer science programs are required to take the GRE General Test and Subject Test in Mathematics or Computer Science. Specific information about the GRE may be obtained from the department of interest.

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

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

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Carlo D. Montemagno, Ph.D., Chair

Scope
Faculty members in the Department of Bioengineering believe that the interface between biology and the physical sciences represents an exciting area for science in the twenty-first century. Bioengineering is establishing 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 engineering students.

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.

Bioengineering B.S.

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

1. Bioengineering 10, 100, 110, 120, 165, 176, 180, 180L, 181, 181L, 182A, 182B, 182C; Biomedical Engineering M186B; Chemical Engineering 101A, M105A; Chemistry and Biochemistry 110A, 153A, 156; Electrical Engineering 102 or Mathematics 115A; Molecular, Cell, and Developmental Biology M140

2. Life Sciences 2 (satisfies HSSEAS GE life sciences requirement), 3, 4

3. Two elective courses from Biomedical Engineering C101, CM102, CM103, CM145, M150, M150L, C170, C171, CM180, C181, C185, CM186L

4. Bioengineering 1, 1L, 2, 2L, 3, 3L (Physics 1A, 1B, 1C or Electrical Engineering 1, 4AL, and 4BL may be substituted for courses 1, 1L, 2, 2L, and 3); Chemistry and Biochemistry 14A, 14B, 14BL, 14C, 14CL, 14D (Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, and 30B may be substituted for the 14 series); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 20

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

Graduate Study
New graduate programs, leading to M.S. and Ph.D. degrees in Bioengineering, are expected to be in place by Fall Quarter 2005. Program requirements will be updated online at http://www.bioeng.ucla.edu, pending final approval.

Faculty Areas of Thesis Guidance

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

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

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

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

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

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

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

Lower Division Courses

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

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

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

2L. Biophysics Laboratory II. (3) Formerly numbered 8L. Lecture, one hour; laboratory, four hours; outside study, four hours. Requisite: course 1L or Physics 4AL. Corequisite: course 2 or Physics 1B. Continuation of second introduction to experimental physics laboratory course that explores basic physical concepts from biological perspective. Topics include behavior of ideal gases, thermal transport, electric field, currents in aqueous media, simple electric circuits of resistors, inductors, and capacitors, electric circuit analogs in biological systems, optics of microscope, physics of light, emission and absorption, fluorescence, laser in biology. Letter grading. Mr. Schmidt (W)

3. Introduction to Biophysics III. (4) Lecture, four hours; outside study, eight hours. Requisites: course 2 or Physics 1B, Mathematics 31B. Corequisite: Mathematics 32A. Introduction to biophysics and biological physics. Basic topics in physics from biological perspective and discussion of physical processes associated with biological phenomena. Topics include DC circuits, simple electric circuits of resistors, inductors, and capacitors, electric circuit analogs in biological systems, optics of microscope, physics of light, emission and absorption, fluorescence, laser in biology. Letter grading. Mr. Schmidt (Sp)

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

10. Introduction to Bioengineering. (2) Lecture, two hours; outside study, four hours. Preparation: high school chemistry, biology, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields of bioengineering, including biosensors, bioinstrumentation, and biochemical processing, biomechanics, biomaterials, tissue engineering, biotechnology, biological imaging, biomedical optics and lasers, neuromyoeing, and biomolecular machines. Letter grading. Mr. Montemagni (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 illustrating many paths of discovery at UCLA. P/NP grading.

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

Upper Division Courses

100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 101A or 101A (may be counted concurrently), Chemistry 140C or 30A, Mathematics 32B (may be counted concurrently). Fundamental basis for analysis and design of biogenic and biomedical devices and systems. Material, energy, charge, and force balances. Introduction to network analysis. Letter grading. Mr. Kamei (F)

110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 101A or 101A (may be counted concurrently), Chemistry 152A, Chemistry 324A. Introduction to fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems that involve interactions between bioengineers, including cells, tissues, organs, human body, extracorporeal devices, tissue engineering systems, and biological organs. Introduction to pharmacokinetic analysis. Letter grading. Mr. Kamei (W)

120. Biomedical Transducers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 140C or 30A, Mathematics 32B. Principles of transduction, design characteristics for different measurements, reliability and performance characteristics, and data processing and recording. Emphasis on silicon-based microfabricated and nanofabricated sensors. Novel materials, biocompatibility, biostability. Safety of electronic interfaces. Actuator design and interfacing control. Letter grading. Mr. Grundfest (Sp)

165. Bioethics and Regulatory Policies in Bioengineering. (2) Lecture, two hours; outside study, four hours. Requisite: course 100. Increasing pace of biotechnological development requires intensive preparation for young scientists (i.e., graduate students, postdoctoral scholars, and junior faculty) on issues in bioethics and regulatory policy. Examination of role of scientists in participating in, supporting, or opposing establishment of regulatory frameworks, relationship of biologists and sociocultural movements by general public and individuals, and discussion of role of scientists in public arena, academic institutions, media, and industry. May be appropriate for students who already have some knowledge and/or experience in molecular biology, genetics, or biotechnology. Letter grading. Mr. Wu (F)

176. Principles of Biocompatibility. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 3 or Electrical Engineering 1 or Physics 1C, Chemistry 152A, Mathematics 32B. Biocompatibility and the influence of biologic and molecular levels. Biomechanical compatibility, stress strain constitutive equations, cellular and molecular response to mechanical signals, biochemical and cellular compatibility, immune response. Letter grading. Mr. Wu (F)

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

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

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

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

182A-182B-182C. Bioengineering Capstone Design I, II, III. (2-2-2) Lectures, design seminars, and discussions with faculty advisory panel. Working in teams, students compete to develop innovative bioengineering solutions to meet specific set of design criteria (design and make strongest self-assembled biorobots or most stable UCLA logo or most selective and efficient biomaxor sensors, etc.). Letter grading. 182A. Lecture, two hours; outside study, four hours. Requisites: courses 3L, 120. Development, writing, oral defense of project proposal. 182B. Lecture, two hours; laboratory, three hours; outside study, one hour. Requisite: course 182A. Exploration of different experimental and computational methods. Ordering of specific materials and software that are relevant to student projects. 182C. Lecture, two hours; laboratory, three hours; outside study, one hour. Requisite: course 182B. Construction of student designs, project updates, presentation of final projects in written and oral format, and team competition. Mr. Deming (F, W, Sp)

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

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

199. Directed Research in Bioengineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. 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.
Biomedical Engineering

Interdepartmental Program

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Carlo D. Montemagno, Ph.D., Chair

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Abeer A.H. Alwan, Ph.D. (Bioengineering, Electrical Engineering)
Sally Blower, Ph.D. (Biomatics)
Angelo Caputo, Ph.D. (Dentistry)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)
Peng-Shen Chen, Ph.D., in Residence (Medicine)
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 Demer, M.D., Ph.D. (Cardiology, Physiology)
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Jack L. Feldman, Ph.D. (Neurobiology, Physiological Science)
Harold R. Fetteman, 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)
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*Chih-Ming Ho, Ph.D. (Mechanical and Aerospace Engineering, Ben Rich Lockheed

Martin Professor of Aeronautics, Center for Micro Systems Director)
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J-Woody Ju, Ph.D. (Civil and Environmental Engineering)
William J. Kaiser, Ph.D. (Electrical Engineering)
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Chang-Jin Kim, Ph.D. (Mechanical and Aerospace Engineering)
J. John Kim, Ph.D. (Mechanical and Aerospace Engineering)
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Gary Duckwiler, M.D. (Radiological Sciences)

Alan Garfinkel, Ph.D. (Physiological Science, Cardiology)
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Jeffrey Wang, M.D. (Orthopaedic Surgery)

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Valeryi I. Nenov, Ph.D. (Neurosurgery)
Usha Sinha, Ph.D. (Radiological Sciences)
Imke Schroeder, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Ricky Taira, Ph.D. (Radiological Sciences)
Daniel J. Valentino, Ph.D. (Radiological Sciences)

Adjunct Assistant Professors
Alex Bui, Ph.D. (Radiological Sciences)
Robert Close, Ph.D. (Radiological Sciences)

Scope and Objectives

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

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

### Graduate Study

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

The following introductory information is based on the 2004-05 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the Publications link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.

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

#### Biomedical Engineering M.S.

Students are expected to complete 42 units, which in most cases include Biomedical Engineering C201, CM202, CM203, and two courses from their area of study. The M.S. degree is offered under both the thesis plan and comprehensive examination plan. Under the thesis plan, 8 units of thesis work may be applied toward the unit requirements for the degree. The comprehensive examination plan consists entirely of coursework (12 courses) and a comprehensive examination on the written portion of the Ph.D. preliminary examination. Students are examined on the core body of knowledge represented by Biomedical Engineering C201, CM202, and CM203. Eight of the 12 courses must be graduate (200-level) courses, and students must maintain a grade-point average of B or better in both upper division and graduate courses. Three Biomedical Engineering 299 courses (6 units total) are also required.

#### Biomedical Engineering Ph.D.

The Ph.D. program prepares students for advanced study and research in biomedical engineering. Students must pass written and oral preliminary examinations on the core body of knowledge represented by Biomedical Engineering C201, CM202, and CM203, an oral qualifying/advancement to candidacy examination, and coursework for two minor fields of study and defend the dissertation. The major field consists of six courses, and each minor field consists of three 4-unit courses, of which two must be graduate (200-level) courses. One minor must be in another field of biomedical engineering. Students must maintain a grade-point average of 3.25 or better in all courses.

#### Fields of Study

**Bioacoustics, Speech, and Hearing**

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

A graduate student videotapes his fabricated hybrid microrobots through a digital imaging system.

#### Course Requirements

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


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

#### Biocybernetics

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

The program provides directed interdisciplinary biosystem studies to establish a foundation in system and information science, mathematical modeling, measurement and integrative biosystem science, as well as related specialized life sciences domain studies. It fosters careers in research and teaching in engineering, medicine, and/or the biomedical sciences, 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, pharmaco-kinetics, and pharmacodynamics; vision, robotics, speech processing, neuroscience, artificial and real neural network modeling, norma-
tive expert systems, wireless remote sensing systems, telemedicine, visualization, and virtual clinical environments.

Course Requirements
Biocybernetics can serve as a minor field for other Ph.D. majors if students complete the following courses with a grade-point average of B+: Biomedical Engineering M186B, M296A, and one additional graduate-level elective from the additional foundations or electives list.

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

Additional Foundations Courses. Biomedical Engineering M269B; Electrical Engineering 131A, 141, 142; Mathematics 115A, 115B, 151A, 151B, 170A; Statistics 100A, 100B.


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

Course Requirements
Core Courses (Required). Biomedical Engineering C201, CM202, CM203, and two courses from CM240, CM260, C281, C282, C285.


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

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


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

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

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


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

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

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


Neuroengineering
The neuroengineering field is a joint endeavor between the Neuroscience Interdepartmental Ph.D. Program in the School of Medicine and the Biomedical Engineering Interdepartmental Graduate Program in HSS/EEAS, with the active involvement of scientists and technologies from the Jet Propulsion Laboratory (JPL).

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

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

Written Preliminary Examination. Before the beginning of the second year, students take a written preliminary examination in neuroengineering and are examined on neuroengineering materials covered in Biomedical Engineering M260 and M263 and neuroscience materials covered in Neuroscience M202 and either M201 or 205.

Students who are in a field other than neuroscience and who select neuroengineering as a minor must take Biomedical Engineering M260 and at least one course from two of the following sets of courses:

(1) Biomedical Engineering M214A, Electrical Engineering 210A, (2) Biomedical Engineering M250A, M250B, (3) Biomedical Engineering M263, Neuroscience M202. Required Courses. Biomedical Engineering M260, M263, Neuroscience M202. For MEMS emphasis, required courses are Biomedical Engineering M150L, M250A, M250B (course M150L is optional if the requisite for course M250A is met). For signal processing and informatics theory emphasis, required courses are Biomedical Engineering M214A and Electrical Engineering 210A, or two other graduate-level engineering courses approved by the adviser and the neuroengineering field chair. In addition, students are required to take a research seminar and problem-based approaches to neuroengineering seminar.

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

Biomedical engineering category: Biomedical Engineering C201.
Neuroscience category: Neuroscience M201, M263, M273, 274.
Students without previous exposure to MEMS should take Biomedical Engineering M150L; those without previous exposure to neuroscience should take Physiological Science 111A; those without previous exposure to signal processing should take Electrical Engineering 102 and 113. Both courses are offered every quarter.

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

Research Seminars. In addition to the formal coursework listed above, all students attend a series of weekly research seminars that allow both students and faculty to become more conversant with the broad range of subjects in neuroengineering. In Fall Quarter, a series called Meet the Professors consists of informal talks by UCLA faculty members and collaborative researchers from the surrounding area. The series introduces the faculty to the students and vice versa, and helps faculty in neuroscience and engineering discover opportunities for collaboration that engage students in the neuroengineering program. In Winter and Spring Quarters, seminar speakers are selected from commercial, academic, and government organizations.

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

Lower Division Courses

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.
99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

C101. Introduction to Biomedical Engineering. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Designed for physical sciences, life sciences, and engineering students. Introduction to wide scope of biomedical engineering via treatment of selected important individual topics by small team of specialists. Concurrently scheduled with course C201. Letter grading. Mr. Kabo (F)
CM102. Basic Human Biology for Biomedical Engineers I. (4) Same as Physiological Science CM102. Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM202. Letter grading. Mr. Montemagno (F)
M150. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laborotory. (2) (Same as Electrical Engineering M150L and Mechanical and Aerospace Engineering M190L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Corequisite: course M150L. Hands-on 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 fabrication processes capable of achieving desired MEMS device. Letter grading.  
Mr. Judy (F)

C151. Nanofabrication of Biomedical Systems Using Nonconventional Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: course M150L or Mechanical and Aerospace Engineering 156A. Hands-on laboratory pertinent to biological and biomedical researchers. Topics include optical microscopy, device characterization, and applications of nontraditional substrates and materials in fabrication of biomedical nanosystems. Materials and fabrication issues, post-processing integration, compatibility with standard processes, and standard fabrication environments. Concurrently scheduled with course C220L. Letter grading.

Mr. Montemagni (W)

C170. Energy-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Chemical Engineering 153, or course C170L. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C270L. Letter grading.  
Mr. Grundfest (F)

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


CM180. Introduction to Biomaterials. (4) (Same as Materials Science CM180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, and 20L, or Materials Science 14. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280L. Letter grading.  
Mr. Wu (W)

C181. Biomaterials-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Requisite: course CM180L. 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 C281L. Letter grading.  
Mr. Wu (Sp)

Mr. Wu (Sp)

M186A. Introduction to Cybernetics, Biomodeling, and Biomedical Computing. (2) (Formerly numbered M196A.) (Same as Computer Science CM186A and Cybernetics M186A.) Lecture, two hours. Requisites: Mathematics 31A, 31B, Program in Computing 10A. Strongly recommended for students with potential interest in biomimetic systems, including putting fields or in Cybernetics as a major. Introduction and survey of topics in cybernetics, biomodeling, biocomputing, and related bioengineering disciplines.

Lectures presented by faculty currently performing research in one of the areas; some sessions include laboratory tours. P/NP grading.  
Mr. DiStefano (W)

Mr. Grundfest (W)

M186L. Biomedical Systems/Biocomputations Research Laboratory. (2 to 4) (Formerly numbered CM198L.) (Same as Computer Science CM186L and Biomedical Engineering CM186L.) Biomedical: two hours; laboratory, two hours. Requisite: course M186B. Special laboratory techniques and experience in biocomputations research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Special research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory automation and safety. Comprehensive experimental design. Radioactive isotopes and kinetic studies. Experimental animals, controls. Concurrently scheduled with course CM296L. Letter grading.  
Mr. DiStefano

188. Special Courses in Biomedical Engineering. (4) (Formerly numbered 198.) Lecture, four hours: outside study, eight hours. Special topics in biomedical engineering for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. Letter grading.

Graduate Courses

C201. Introduction to Biomedical Engineering. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Designed for physical sciences, life sciences, and engineering students. Introduction to wide scope of biomedical engineering via treatment of selected important individual topics by small team of specialists. Concurrently scheduled with course C101L. Letter grading.  
Mr. Kobo (F)
CM202. Basic Human Biology for Biomedical Engineers I. (4) (Same as Physiological Science CM202.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. A broad overview of basic biological activities and organization of human body in system (organ/tissue) level, with particular emphasis on functional aspects of biological system. Model/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical centers are usually scheduled with course CM102. Letter grading.

Mr. Montemagno (F)


Mr. Montemagno (W)


Ms. Alwan (W)

M215. Biochemical Reaction Engineering. (4) (Same as Chemical Engineering CM215.) Lecture, four hours; outside study, eight hours. Prerequisites: 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. Geared toward nonphysicists. Letter grading.

M217. Biomedical Imaging. (4) (Same as Electrical Engineering M217.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Prerequisite: Electrical Engineering 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, positron emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, image reconstruction algorithms, system configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. Letter grading.

Mr. Wu (F)

221. Human Anatomy and Physiology for Medical Informatics. (4) Lecture, four hours; outside study, eight hours. Corequisite: course 222. Designed for graduate students interested in human anatomy and physiology, with particular emphasis on visualization of anatomy and physiology from imaging perspective. Topics include chest, cardiac, neurology, gastrointestinal/guitorinary, and musculoskeletal systems. Examination of basic imaging physics (magnetic resonance, computed tomography, ultrasound, computed radiography) to provide context for imaging systems. Projects may be custom-designed and selected by the student. Letter grading.

Mr. Wu (F)

222. Clinical Rotation Medical Informatics. (2) Lecture, two hours; laboratory, four hours. Corequisite: course 221. Designed for graduate students. Clinical rotation through medical imaging modalities and clinical environments. Exposure to challenges of medical practice today and clinical usage of imaging, including computed tomography, magnetic resonance, and other traditional forms of image acquisition. Designed to provide students with real-world exposure to state-of-the-art modalities as well as current practices, imaging, and information systems. Participation in clinical noon conferences to further broaden exposure and understanding of medical problems. S/U grading.

Mr. Wu (F)

223A-223B-223C. Programming Laboratories for Medical Informatics I, II, III. (4-4-4) Lecture, two hours; laboratory, two hours. Designed for graduate students. Laboratory/clinical exposure to basic concepts related to networking at the Internet level (network topologies, and high-level (distributed computing, Web-based services) implementations. Commonly used medical communication protocols (HLP, DICOM) and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless, Internet2/gigabit networks, peer-to-peer technologies. Introduction to security and encryption in networked environments. Letter grading.

Mr. Wu (F)

224A. 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 principles of imaging techniques behind different modalities, with exposure to seminal works. Current research efforts, with focus on clinical applications and new types of information available. Geared toward nonphysicists. Letter grading. S/U grading.

Mr. Wu (Sp)

M225. Bioseparations and Bioprocess Engineering. (4) (Same as Chemical Engineering CM225.) Lecture, four hours; outside study, eight hours. Requisite: Chemical Engineering 101C and 103, or Chemistry 156. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Letter grading.

Mr. Monbouquette (W)

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

Mr. Wu (Sp)

227. Medical Information Infrastructures and Internet Technologies. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to networking, communications, and information infrastructures in medical environment. Exposure to basic concepts related to networking at several levels: low-level (TCP/IP, services), medium-level (network topologies, and high-level (distributed computing, Web-based services) implementations. Commonly used medical communication protocols (HLP, DICOM) and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless, Internet2/gigabit networks, peer-to-peer technologies. Introduction to security and encryption in networked environments. Letter grading.

Mr. Wu (F)

228. Medical Decision Making. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluations. Application of medical decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing, and estimation. Focus on technical advances in medical decision support systems and expert systems, with review of classic and current research. Introduction to common statistical and decision-making software packages to familiarize students with current tools. S/U grading.

Mr. Wu (W)
230. Engineering Principles of Ultrasound. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to science and technology of acoustics in biological systems, starting with physical acoustics, acoustic wave (Helmholtz) equation, acoustic propagation and scattering in homogeneous and inhomogeneous media, and acoustic attenuation. Examination of physical and biological properties of tissue. Students with permission can elect this course for doctoral credit. Concurrently scheduled with course CM140. Letter grading.

CM240. Introduction to Biomechanics. (4) Same as Mechanical and Aerospace Engineering CM240.) Lecture, four hours; outside study, eight hours. Requirement: Civil Engineering 108 or Mechanical and Aerospace Engineering 102, 156A. Introduction to the mechanical behavior of human body: skeletal, muscular, and nervous systems. Concurrently scheduled with course CM140. Letter grading.

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

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

M250A. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Electrical Engineering M250A and Mechanical and Aerospace Engineering M282L.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requirement: course M150L. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading.


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

M260. Neuroengineering. (Formerly numbered 260.) (Same as Neuroscience M260.) Lecture, four hours; laboratory, three hours. Requirement: Mathematics 32A, 32B, 32C, 18A, 18B, 18C. Introduction to principles and technologies of neural recording and stimulation. Neurophysiology: clinical electrophysiology (EEG, evoked potentials, inverse problem, preoperative brain recordings, extracellular microelectrodes and recording field potentials and single units), chronic recording with extracellular electrodes; electrode biocompatibility. Tissue damage, electrode and cable survival, intracellular recording and glass pipettes electrodes, iontophoresis; imaging neural activity (Ca imaging, voltage-sensitive dyes), intrinsic optical imaging; MRI, fMRI. Letter grading.


M263. Neuroanatomy: Structure and Function of Nervous System. (4) (Formerly numbered M263A-M263B.) (Same as Neuroscience M263.) Lecture, three hours; discussion/laboratory, three hours. Anatomy of central and peripheral nervous system at cell, cellular, histological and regional systems level, with emphasis on experimental contemporary approaches to morphological study of nervous system in discus- sions of circuitry and neurochemical anatomy of major brain regions. Consideration of representative vertebrados and invertebrate nervous systems. Letter grading.


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


C282. Biomedical Interfaces. (4) Lecture, three hours; outside study, nine hours. Requirement: course CM180 or CM280. Function, utility, and biocompatibility of biomaterials depend critically on their surface and interfa- cial properties. Discussion of morphology and composition of biomaterials and nanoscales, mesoscales, and macroscales. Techniques for characterizing structure and properties of biomaterial interfaces, and methods for designing and fabricating biomaterials with prescribed structure and properties in vitro and in vivo. Letter grading.

295A. Nanotechnology Research.

295B. Biomaterials and Tissue Engineering Research.

295C. Minimally Invasive and Laser Research.

295D. Hybrid Device Research.

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

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


M296D. Introduction to Computational Cardiology. (4) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course M196B. Introduction to mathematical modeling and 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).
semiconductor processing, chemical vapor deposition, plasma processing and simulation, electrochemistry corrosion, and polymer engineering.

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

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

**Undergraduate Program Objectives**

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

**Chemical Engineering B.S.**

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

**The Major**

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

1. Three general engineering courses: Chemical Engineering M105A, Civil and Environmental Engineering 108, Electrical Engineering 100
3. Two elective courses from Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C125, C140, and three upper division chemical engineering elective courses (except Chemistry and Biochemistry 110A). An upper division life or physical sciences course may be substituted for one chemistry elective with the approval of the faculty adviser
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

**Biomedical Engineering Option**

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

1. One general engineering course: Chemical Engineering M105A
3. Two elective courses from Chemical Engineering C115, C125, CM145 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser); one upper division ecology and evolutionary biology or microbiology, immunology, and molecular genetics or molecular, cell, and developmental biology elective that requires one year of chemistry as a requisite
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Life Sciences 1, 2, 3; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

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

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

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

1. Three general engineering courses: Chemical Engineering M105A, Electrical Engineering 100, Materials Science and Engineering 14
3. Two elective courses from Chemical Engineering C112, 113, C114, C116, C118, C119, C140 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser) and two chemistry elective courses (except Chemistry and Biochemistry 110A)
4. Chemistry and Biochemistry 20A, 20B, 20L, 30AL; Civil and Environmental Engineering 15 or Mechanical and Aerospace Engineering 20; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL
5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

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

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

The following introductory information is based on the 2004-05 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the Publications link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.

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

Chemical Engineering M.S.
Areas of Study
Consult the department.

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

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

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

A program of study which encompasses these requirements must be submitted to the departmental Student Affairs Office for
approval before the end of the student's second quarter in residence.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, M105A, 105D, 199.

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

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

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

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

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

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

Chemical Engineering Ph.D.

Major Fields or Subdisciplines
Consult the department.

Course Requirements
All Ph.D. students must take six courses (24 units), including Chemical Engineering 200, 210, and 220. Two additional courses must be taken from those offered by the Chemical 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 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 Engineering, in accordance with University regulations. The written qualifying examination consists of a dissertation research proposal that provides a clear description of the problem considered, a literature review of the current state of the art, and a detailed explanation of the approach to be followed to solve the problem. Students first present their ideas for the dissertation research at a precandidacy seminar administered by departmental faculty members of the doctoral committee. The seminar is held during the early part of the Winter Quarter of the second year in residence. Following the seminar, students submit the dissertation research proposal to the doctoral committee. The written examination is due in the seventh week of the Winter Quarter. The University Oral Qualifying Examination consists of an oral defense of the dissertation research proposal and is administered by the doctoral committee. The oral examination is held within two weeks of submitting the written examination.

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

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

Organic synthesis reactions catalyzed by electrochemically active redox enzymes such as cytochrome P450cam are studied using customized equipment for cyclic voltammetry, potential-step transient-decay analysis, and coulometry. Enzymes are studied in free aqueous solution and in membrane mimetic media such as micelles, vesicles, and adsorbed layers. A Wyatt Dawn F HeNe laser photometer is used to characterize micelles and vesicles. Modern analytical equipment supports biochemical engineering research, including a Beckman DU-65 scanning spectrophotometer outfitted with a customized cuvette for spectroelectrochemical studies; two HPLCs, a Beckman and a Spectrophysics unit suitable for preparative-scale separations; and three gas chromatographs, one equipped with an electron capture detector.

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

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

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

Electronic Materials Processing Laboratory
The Electronic Materials Processing Laboratory focuses on synthesizing and processing novel electronic materials for their applications in microelectronics, micro-optoelectronics, and micro-electromechanical systems (MEMS). Areas of interest include novel dielectric materials, advanced thermal and plasma processing, surface and interface kinetics, and solid-state electronic devices and chemical and biological MEMS fabrication. The laboratory is equipped with a state-of-the-art advanced rapid thermal processing facility with in-situ vapor phase processing and atomic layer deposition capabilities; advanced plasma processing tools including thin film deposition and etching; a surface analytical facility including X-ray photoelectron spectroscopy, Auger electron spectroscopy, ultra-violet photoelectron spectroscopy, reflection high energy electron diffraction, spectroscopic ellipsometry, and infrared spectroscopy; and a complete set of processing tools available for microelectronics and MEMS fabrication in the Nanoelectronic Research Facility. With the combined material characterization and electronic device fabrication, the reaction kinetics including composition and morphology, and the electrical property of these materials can be realized for applications in the next generation electronic devices and chemical or biological MEMS.

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. Stu-
OMVPE processes for synthesizing high-performance optoelectronic devices.

**Polymer and Separations Research Laboratory**

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

**Process Systems Engineering Laboratory**

The Process Systems Engineering Laboratory is equipped with state-of-the-art computers for transmission and scanning electron microscopy. Located near the laboratory, the Electron Microscopy facilities staff provide instruction and assistance in the use of these instruments. Advanced electron microscopy has recently been used in the laboratory to make the first systematic studies of atmospheric nanoparticle chain aggregates. Such aggregate structures have been linked to public health effects and to the absorption of solar radiation. A novel nanostructure manipulation device, designed and built in the laboratory, makes it possible to probe the behavior of nanoparticle chain aggregates of a type produced commercially for use in nanocomposite materials; these aggregates are also released by sources of pollution such as diesel engines and incinerators.

**Optoelectronic Materials Processing Laboratory**

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

Knowledge gained from research in this laboratory may be used to develop new SEASNet and campuswide computational facilities, is available to LAN users. Software for simulation and optimization of general systems includes MINOS, GAMS, MATLAB, CPLEX, and LINDO. Software for simulation of chemical engineering systems includes HYSYS for process simulation and CACHE-FUJITSU for molecular calculations. UCLA-developed software for heatpower integration and reactor network attainable region construction are also available.

**Faculty Areas of Thesis Guidance**

**Professors**

Yoram Cohen, Ph.D. (Delaware, 1981)  
Separation processes, graft polymerization, surface nanostructuring, macromolecular dynamics, pollutant transport and exposure assessment

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

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

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

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

Yoram Cohen, Ph.D. (Delaware, 1981)  
Separation processes, graft polymerization, surface nanostructuring, macromolecular dynamics, pollutant transport and exposure assessment

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

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

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

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

**Professors Emeriti**

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

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

William D. Van Vorst, Ph.D. (UCLA, 1953)  
Chemical engineering: thermodynamics, energy conversion, alternative energy
systems, hydro- and alcohol-fueled engines
A.R. Frank Wazzan, Ph.D. (UC Berkeley, 1963)
Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer

Associate Professors
Jane P. Chang, Ph.D. (MIT, 1998)
Letter grading. Mr. Cohen, Mr. Friedlander (F)
flows in conduits and around submerged objects.

Newton law of viscosity, Navier/Stokes equations, in-f
fluid flow in systems of interest to chemical engineering prac-
tice. Fundamentals of thermal energy transport, Fou-
rier law of heat conduction, forced and free convec-
tion, radiation, interphase heat transfer, heat ex-
changer design. Mr. Chau, Mr. Hicks (W)

101C. Mass Transfer. (4) Lecture, four hours; dis-
cussion, one hour; outside study, seven hours. Requi-
sites: courses 100, 101B, 102. Introduction to anal-
ysis of mass transfer in systems of interest to chemi-
cal engineering practice. Fundamentals of mass 
Species transport. Fick law of diffusion, diffusion in chemically reacting flows, interphase mass transfer,  
multipurpose systems. Letter grading.
Mr. Hicks (Sp)

102. Chemical Engineering Thermodynamics. (4) 
Lecture, four hours; outside study, eight hours. Req-
uisites: courses 100, M105A. Thermodynamic prop-
ties of pure substances and solutions. Phase equi-
librium. Chemical reaction equilibrium. Letter grad-
ing.

Mr. Nobe (W)

103. Separation Processes. (4) Lecture, four hours; 
outside study, eight hours. Prerequisites: courses 100,  
101B, 102. Application of principles of heat, mass, 
and momentum transport to design and operation of 
separation processes such as distillation, gas ab-
sorption, filtration, and reaction. Multiple-scale grad-
ing.
Ms. Chang, Mr. Hicks (Sp)

104A. Chemical Engineering Laboratory I. (6) 
Lecture, two hours; laboratory, eight hours; outside 
study, four hours; other, four hours. Requisites: 
courses 100, 101B, 102. Measurements of tempera-
ture, pressure, flow rate, viscosity, and solid composi-
tion in chemical processes. Methods of data acquisi-
tion, equipment selection and fabrication, and labora-
tory safety. Development of technical writing, and oral 
communication skills. Letter grading. 
Mr. Hicks (W/Sp)

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

104C. Semiconductor Processing Laboratory. (6) 
Lecture, two hours; laboratory, eight hours; outside 
study, four hours; other, four hours. Requisites or 
course 104A, Electrical Engineering 2. Series of experi-
ments that emphasize basic engineering principles of 
semiconductor processing, including fabrication, and 
characterization of semiconductor devices. In-
vestigation of processing steps used to make CMOS 
devices, including wafer cleaning, oxidation, diffu-
sion, lithography, chemical vapor deposition, 
process etching, and metallization. Presentation of student re-
sults in both written and oral form. Statistical design 
of experiments and error analysis. Letter grading. 
Ms. Chang, Mr. Hicks (W)

105A. Introduction to Engineering Thermody-
namics. (4) (Same as Mechanical and Aerospace 
Engineering M105A.) Lecture, four hours; discussion, 
one hour; outside study, seven hours. Requisites: 
Chemistry 2, Mathematics 32B, 33A, 33B. Corequisite: 
course 109. Introduction to analysis of fluid flows in systems of interest to chemical engineer-
ing practice. Fundamentals of momentum transport, 
Newton law of viscosity, Navier/Stokes equations, in-
terphase momentum transport and friction factors, 
flows in connected and submerged objects. Letter grading. 

Mr. Cohen, Mr. Friedlander (F)

101B. Heat Transfer. (4) Lecture, four hours; discus-
sion, one hour; outside study, seven hours. Requisite: 
course 101A. Introduction to analysis of heat transfer 
in systems of interest to chemical engineering prac-
tice. Fundamentals of thermal energy transport, Fou-
rier law of heat conduction, forced and free convec-
tion, radiation, interphase heat transfer, heat ex-
changer design. Mr. Chau, Mr. Hicks (W)

106. Chemical Reaction Engineering. (4) Lecture, 
four hours; outside study, eight hours. Requisites: 
courses 100, 101C, 102. Fundamentals of chemical 
kinetcis and catalysis. Introduction to analysis and 
design of homogeneous and heterogeneous chemi-
cal reactors. Letter grading.

Mr. Senkan (F)

107. Process Dynamics and Control. (4) Lecture, 
four hours; outside study, eight hours. Requisites: 
courses 101C, 103, 106. Principles of dynamics 
modeling and start-up behavior for chemical engi-
neering processes. Chemical process control ele-
ments. Design and applications of chemical process 
computer control. Letter grading.

Mr. Manousiouthakis (W)

108A. Process Economics and Analysis. (4) Le-
ture, four hours; outside study, eight hours. Requi-
sites: courses 103, 104B, 106. Integration of chemi-
cal engineering fundamentals such as transport phe-
nomena, thermodynamics, separation operations, 
and reaction engineering and simple economic prin-
ciples for purpose of designing chemical processes and 
evaluating alternatives. Letter grading. 
Mr. Manousiouthakis (W)

108B. Chemical Process Computer-Aided Design 
and Analysis. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 106, 108A, 
Computer Science 10F. Introduction to application of 
some mathematical and computational tools to 
chemical engineering design problems; use of simu-
lation programs as an automated method of perform-
ing steady state material and energy balance calcula-
tions. Letter grading. 
Mr. Manousiouthakis (Sp)

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

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

C111. Cryogenics and Low-Temperature Proceed-
es. (4) Lecture, four hours; discussion, one hour; out-
side study, seven hours. Requisites: courses 102 (or 
Materials Science 130), M105A. Fundamentals of cryoengineering science pertinent to industrial low-temperature processes. Mathematical approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temp-
 erature behavior of matter, optimization of cryosys-
tems and other special conditions. Concurrently 
scheduled with course C211. Letter grading. 
Mr. Manousiouthakis (F)

C112. Polymer Processes. (4) (Formerly num-
bered 112.) Lecture, four hours. Requisites: course 
101A, Chemistry 30A. Formation of polymers, criteria 
for selecting a reaction scheme, polymerization tech-
niques, polymer characterization. Mechanical proper-
ties. Rheology of macromolecules, polymer process 
engineering. Diffusion in polymeric systems. Poly-
mers in biomedical applications and in microelec-
tronics. Concurrently scheduled with course C122. Letter 
grading. 
Mr. Cohen (Sp)

113. Air Pollution Engineering. (4) Lecture, four 
hours; preparation, two hours; outside study, six 
hours. Requisites: courses 101C, 102. Integrated ap-
proach to air pollution, including concentrations of at-
mospheric pollutants, air pollution standards, air pol-
lution sources and control techniques, and relation-
ship of air quality to emission sources. Links air pollu-
tion to multimedia environmental assessment. 
Letter grading. 
Mr. Friedlander (F)
C114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102 (or Materials Science 130), M105A. Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Specific emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Letter grading. Mr. Nobe (F)

C115. Biochemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisites: courses 101C and 106, or Chemistry 156. Use of previously learned concepts of physical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course C214. Letter grading. Mr. Nobe (F)

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


C120. Bioseparations and Bioprocess Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101C and 103, or Chemistry 156. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently scheduled with course CM225. Letter grading.


Mr. Friendlander (F or W)

C145. Molecular Biotechnology for Engineers. (4) (Same as Biomedical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, eight hours. Special topics in molecular biology that form fundamental knowledge of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, and protein engineering. DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading.

Mr. Liao

C188. Special Courses in Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in chemical engineering for undergraduates that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. May be repeated once with credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current research projects. Letter grading.

199. Directed Research in Chemical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation of selected topic under guidance of faculty mentor. Culminating paper or project required. Only 2 units, approved by petition and used only as replacement for one regular chemical engineering laboratory course, may be applied toward degree. 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. Advanced Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requirements: courses 100C. Phenomenological and statistical thermodynamics of chemical and physical systems with engineering applications. Presentation of role of atomic and molecular spectra and intermolecular forces in interpretation of thermodynamic properties of gases, liquids, solids, and plasmas. Letter grading. Mr. Nobe (F)

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

Mr. Nobe (F)

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

Mr. Senkan (W)

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

Mr. Cohen (W)


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

C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. May be concurrently scheduled with course CM215. Letter grading. Mr. Nobe (F)

CM215. Biochemical Reaction Engineering. (4) (Formerly numbered C215.) (Same as Biomedical Engineering M215.) Lecture, four hours; outside study, eight hours. Prerequisites: courses 101C and 106, or Chemistry 156. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course C114. Letter grading.

Mr. Nobe (F)

C216. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 200 or Chemistry C223A or Physics 215A. Modern simulation techniques for classical molecular Monte Carlo and molecular dynamics in various systems. Applications to liquids, solids, and polymers. Letter grading.

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

Mr. Cohen, Mr. Friedlander (F)

223. Design for Environment. (4) Lecture, four hours; outside study, eight hours. Limited to graduate students. Principles of design for energy efficiency, design for waste minimization, computer-aided design tools, materials selection methods. Letter grading.

CM225. Bioseparations and Bioprocess Engineering. (4) Same as Biomedical Engineering M225.) Lecture, four hours; outside study, eight hours. Requisites: courses 101C and 103, or Chemistry 156. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently scheduled with course C125. Letter grading.

Mr. Liao, Mr. Monbouquette (Sp)


Mr. Senkan (P)

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


Mr. Senkan (Sp)

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

Ms. Chang, Mr. Hicks (Sp)


Mr. Friedlander (F)

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

Mr. Liao


Mr. Liao (W)

250. Computer-Aided Chemical Process Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course CM245. Optimization methods in chemical process design; computer aids in process engineering; process modeling; systematic flow-sheet invention; process synthesis; optimal design and operation of large-scale chemical processing systems. Letter grading.

Mr. Manousiouthakis (F)


Mr. Cohen (Sp)


270R. Advanced Research in Semiconductor Manufacturing. (6) Laboratory, nine hours; outside study, nine hours. Limited to graduate chemical engineering students. Seminar in 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 systems (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvalues and eigenvectors, singular values, Cayley-Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle. Connections with transfer function techniques. Letter grading.


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 techniques, methods and algorithms for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Banach and Hilbert spaces, semigroup theory, convergence theory in function spaces), (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition), (3) nonlinear and robust control of nonlinear hyperbolic and parabolic partial differential equations (PDEs), (4) applications to transport-reaction processes. Letter grading.

Mr. Christofides


Mr. Manousiouthakis

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

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

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

(F,W,Sp)

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

(F,W,Sp)

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

(F,W,Sp)
Civil and Environmental Engineering

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William W-G. Yeh, Ph.D., Chair
Jiun-Shyan Chen, Ph.D., Vice Chair

Professors

Jiun-Shyan Chen, Ph.D.
Jiann-Wen Ju, Ph.D.
Michael K. Stenstrom, Ph.D.
Keith D. Stolzenbach, Ph.D.
Mladen Vucetic, Ph.D.
William W-G. Yeh, Ph.D.

Professors Emeriti

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

Associate Professors

Jonathan P. Stewart, Ph.D.
John W. Wallace, Ph.D.

Assistant Professors

Eric M.V. Hoek
Terri Hogue, Ph.D.
Jennifer A. Jay, Ph.D.
Steven Margulis, Ph.D.
Ertugrul Tacioglu, Ph.D.

Senior Lecturers

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

Adjunct Professors

Ne-Zheng Sun, Ph.D.

Adjunct Associate Professors

Joel P. Conte, Ph.D.
Patrick J. Fox, Ph.D.
Thomas C. Harmon, Ph.D.
Daniel E. Pradel, Ph.D.
Thomas Sabol, Ph.D.

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

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

Undergraduate Program Objectives

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

Civil Engineering B.S.

The Major

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

1. Seven core courses: Chemical Engineering M105A or Mechanical and Aerospace Engineering M105A, Civil and Environmental Engineering 1, 108, Electrical Engineering 103, Materials Science and Engineering 14, Mechani-
ical and Aerospace Engineering 102, 103

2. Civil and Environmental Engineering
120, 121, 130, 135A, 150, 151, 153;
one course involving a major design
project from Civil and Environmental
Engineering 135L, 144, 147, 157B,
157C, 157L; Civil and Environmental
Engineering 110 and Mechanical and
Aerospace Engineering 182A

3. Twenty-eight elective units, to be
selected from the courses listed below,
which must include 8 units of laboratory
in at least two major field areas and at
least 16 units of design:

   Engineering Mechanics. Civil and Envi-
   ronmental Engineering 130L, Mechanical
   and Aerospace Engineering 166C, 168

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

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

   Systems Analysis. Civil and Environ-
   mental Engineering 106A

   Transportation Engineering. Civil and
   Environmental Engineering 180

   Water Resources and Environmental
   Engineering. Civil and Environmental
   Engineering 154, 155, 156A, 156B,
   157B, 157C, 163, 164, M166, 166L

4. Chemistry and Biochemistry 20A, 20B,
20L; Civil and Environmental Engineer-
ing 15; Mathematics 31A, 31B, 32A,
32B, 33A, 33B; Physics 1A, 1B, 1C,
4AL, 4BL

5. HSSEAS general education (GE)
requirements; see Curricular Require-
ments on page 21 for details

Graduate Study

For information on graduate admission,
see Graduate Programs, page 23.
The following introductory information is
based on the 2004-05 edition of Program
Requirements for UCLA Graduate Degrees.
Complete annual editions of Program
Requirements are available from the
ucla.edu. Students are subject to the
degree requirements as published in Pro-
gram 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 Environ-
mental 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 involv-
ing work on the thesis. In the compre-
prehensive 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 pre-
paratory courses which are normally com-
dleted during undergraduate studies.
Equivalent courses taken at other institu-
tions can satisfy the preparatory course
requirements. The preparatory courses
cannot be used to satisfy course require-
ments 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

Environmental Engineering

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

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

Elective Courses. Civil and Environmental
Engineering 155, 157B, 157C, 163, 164,
M166, 253, 258A, 263A, 263B, 265A,
265B, 266; a maximum of two of the follow-
ing courses for students electing the thesis
plan or a maximum of three of the following
courses for students electing the compre-
prehensive examination plan: Civil and Envi-
ronmental Engineering 150, 226, 250A,
250B, 250C, 250D, 252, 260, M262A,
M262B, Chemical Engineering 101C or
Mechanical and Aerospace Engineering
105D, Chemical Engineering 106, 210,
C218, 220, C240, Chemistry and Biochemi-
Geotechnical Engineering

Required Preparatory Courses. Civil and Environmental Engineering 108, 120, 121.
Required Graduate Courses. Civil and Environmental Engineering 220, 221, 222, 223, 224.

Major Field Elective Courses. Minimum of three courses must be selected from Civil and Environmental Engineering 125, 222, 225, 226, 227, 228L.


Hydrology and Water Resources Engineering

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

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

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

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

Structural/Earthquake Engineering

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

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


Structural Mechanics

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

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

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

Comprehensive Examination Plan

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

Thesis Plan

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

Civil Engineering Ph.D.

Major Fields or Subdisciplines

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

Course Requirements

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

Written and Oral Qualifying Examinations

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

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

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, must be inside members who hold full-time faculty appointments at UCLA in the student’s major department in HSSEAS. The outside member must be
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 analytical and design tools, as well as design recommendations. Reliability-based design and performance assessment methodologies are also an important field of study.

Facilities

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

Instructional Laboratories

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

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

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

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

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

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

6. **Soil Mechanics Laboratory.** For performing experiments to establish data required for soil classification, soil compaction, shear strength of soils, soil settlement, and consolidation characteristics of soils.

7. **Advanced Soil Mechanics Laboratory.** For presenting and performing advanced triaxial, simple shear, and consolidation soil tests. For demonstration of cyclic soil testing techniques and advanced data acquisition and processing.

Research Laboratories

1. **Experimental Mechanics Laboratory.** For supporting two major activities; the Optical Metrology Laboratory and the Experimental Fracture Mechanics Laboratory.

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

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

2. Large-Scale Structure Test Facility. For investigating the behavior of large-scale structural components and systems subjected to gravity and earthquake loadings. The facility consists of a high-bay area with a 20 ft. x 50 ft. strong floor with anchor points at 3 ft. on center. Actuators with servohydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced by two cranes. The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings. Associated with the laboratory is an electrohydraulic universal testing machine with force capacity of 100 tons. The machine is used mainly to apply tensile and compressive loads to specimens so that the properties of the materials from which the specimens are made can be determined. It can also be used in fatigue-testing of small components.

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

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

5. Environmental Engineering Laboratories. For conducting water and wastewater analysis, including instrumental techniques such as GC, GC/MS, HPLC, TOC, IC, and particle counting instruments. A wide range of wet chemical analysis can be made in this facility with 6,000 square feet of laboratory space and an accompanying 4,000-square-foot rooftop facility where large pilot scale experiments can be conducted. Additionally, electron microscopy is available in another laboratory.

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

Facility Areas of Thesis Guidance

Professors

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

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

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

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

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

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

Professors Emeriti

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

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

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

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

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

Tung Hua Lin, D.Sc. (Michigan, 1963)
Plasticity and creep, micromechanics and constitutive relations of metals, elastic-plastic analysis of structures; creep analysis of structures

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

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

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

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

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

Associate Professors

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

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

Assistant Professors

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

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

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

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

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

Mr. Ju (F)


Mr. Yeh (W)

108. Introduction to Mechanics of Deformable Solids. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 32A, 33A. Introduction to fundamental concepts and applications of probability and statistics in civil engineering, with focus on how these concepts are used in experimental design and sampling, data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distribution, functions of random variables, estimating parameters from observational data, regression, hypothesis testing, and Bayesian concepts. Letter grading.

Mr. Markulis (Sp)

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

Mr. Stewart (F)

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

Mr. Stewart (W)

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

Mr. Stewart (Sp)


Mr. Stewart (Sp)

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

Mr. Vucetic (F,Sp)

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

Mr. Markulis (Sp)


Mr. Ju (W)

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

Mr. Ju (F)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 130, 135B. Direct approach for truss analysis, direct form and weak form, approximation functions for finite element methods, weighted residual methods, Ritz method, variational method, convergence criteria and rate of convergence, natural coordinates and shape functions, isoparametric finite elements, finite element formulation of multidimensional heat flow and elasticity, numerical integration and approximation properties, finite element formulation of beam. Letter grading.

Mr. Chen, Mr. Ju (Sp)


Mr. Ju (Sp)
137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics for civil engineering students, and critical free, forced vibration, and earthquake response spectra analysis for single and multidegree of freedom systems. Axial, bending, and torsional vibration of beams and columns. Mr. Wallace (F)
137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 137. Calibration of instrumentation for dynamic measurements. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies, mode shapes, and damping factors from forced vibrations. Dynamic similarity. Letter grading.
Mr. Wallace (F)

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

142. Reinforced Concrete Structural Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite: course 142. Limited enrollments considered for reinforced concrete beams, columns, slabs, and slabs. Experiments using analysis and experiments. Links between technical theory, building codes, and experimental results. Letter grading. Mr. Wallace (Sp)

143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 135A, 142. Prestressing and post-tensioning techniques. Properties of concrete and prestressing steels. Design considerations: anchorage/bonding of cables/wire, flexure analysis by superposition and strength methods, deflection of cables, deflection and stiffness, indeterminate structures, limit state design. Letter grading. Mr. Wallace (Sp)


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

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

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Mechanical and Aerospace Engineering 103. Principles of hydraulic flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydropower, photovoltaic, introduction to system analysis and design of water resources engineering. Letter grading. Ms. Hogue (W)

153. Introduction to Environmental Engineering Science. (4) Lecture, four hours; outside study, four hours. Requisite: Mechanical and Aerospace Engineering 103. Principles of hydraulic flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydroelectric power, introduction to system analysis and design of water resources engineering. Letter grading. Ms. Hogue (W)

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

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


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

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

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

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

194. Research Group Seminars: Civil and Environmental Engineering. (4) Seminar. Four hours; outside study, eight hours. Designed for undergraduates 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.

221. Advanced Foundation Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 121, 220. Stress distribution. Bearing capacity and settlement of shallow foundations, including spread footings and mats. Performance of driven pile and drilled shaft foundations under vertical and lateral loading. Consideration of geotechnical principles to design piles, and excavation bracing. Effects of flexibility, creep in soils, and construction techniques on stability of footings and sheet piles. Mechanical stabilization of soils, such as with soil nails and geosynthetics. Letter grading.

Mr. Stewart (Sp)

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

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

Mr. Stewart (Sp)


225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 137. Analysis of earthquake ground motions, including seismic source modeling, travel path effects, and site response effects. Postcyclic seismic hazard analysis. Soil liquefaction. Seismic slope stability. Letter grading.

Mr. Stewart (W)

226. Geoenvironmental Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental regulation, geotechnical evaluation of solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading.

Mr. Stewart (Sp)

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

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

M230A. Mechanics of Deformable Solids. (4) (Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 156A or 166A. Development of fundamental principles and equations of solid mechanics. Cartesian tensors; kinematics of large deformations; balance laws of mass, momentum, and energy; constitutive relations of elasticity, thermoelasticity, and viscoelasticity for isotropic and anisotropic solids; solution of selected problems. Letter grading.

Mr. Ju, Mr. Mal (F)

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

Mr. Ju, Mr. Mal (W)

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

Mr. Ju (F)


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

Mr. Ju (Sp)

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

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, 235A. Direct energy formulations for deformable systems; solution methods for linear equations; analysis of structural systems with one-dimensional elements; introduction to variational calculus; discrete element displacement, force, and mixed methods for mechanics of structures; instability effects. Letter grading. Mr. Chen (W)

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


Mr. Chen (Sp)


Mr. Ju (Sp)

243A. Behavior and Design of Reinforced Concrete Structural Elements. (4) Lecture, four hours; outside study, eight hours. Requisite: course 142. Advanced topics on design of reinforced concrete structures, including stress-strain relationships for plain and confined concrete, moment-curvature analysis of sections, and design for shear. Design of slender and low-rise walls, as well as design of beam-column joints. Introduction to displacement-based design and applications of strut-and-tie models. Letter grading. Mr. Wallace (F)

243B. Response and Design of Reinforced Concrete Structural Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 243A, 246. Information on response and behavior of reinforced concrete buildings to earthquake ground motions. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, and ductility in design, use of prescriptive versus performance-based design methodologies, and application of elastic and inelastic analysis techniques for new and existing construction. Letter grading. Mr. Wallace (W)

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

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


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

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

250A. Surface Water Hydrology and Hydrometeorology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150. In-depth study of surface water components of hydrologic cycle and their connection to atmosphere. Precipitation and evaporation processes, exchange of mass, heat, and momentum between soil and vegetation surface and overlying atmosphere, flux and transport in turbulent boundary layer, infiltration and runoff production, 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 (F)

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 uncertainty and risk analysis of flood forecasting and prediction of streamflows in water resource applications. Lecture grading. Ms. Hogue (Sp)

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

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

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


254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture, four hours; outside study, eight hours. Requisites: Chemistry 20B, Mathematics 31A, 31B, Physics 1A, 1B. Equilibrium and kinetic descriptions of chemical behavior of metals and inorganic ions in natural fresh/marine surface waters and in water treatment. Processes include acid-base chemistry and alkalinity (carbonate system), complexation, precipitation/dissolution, 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. Fundamentals of physical and chemical reaction engineering, coagulation and flocculation, granular filtrations, sedimentation, carbon adsorption, gas transfer, disinfection, oxidation, and membrane processes. Letter grading. Mr. Stenstrom (W)

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

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

259A. Selected Topics in Environmental Engineering. (2) Lecture, two hours; outside study, four hours. Requisite: course 254A. 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. Stenstrom (W)

259B. Selected Topics in Water Resources. (2 to 4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Review of recent research and developments in water resources. Water supply and hydrology, global climate change, economic planning, optimization of water resources development. May be taken for a maximum of 4 units. Letter grading. Mr. Stenstrom (F, W, Sp)

260. Advanced Topics in Hydrology and Water Resources. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B, 251. Current research topics in inverse problem of parameter estimation, experimental design, conjunctive use of surface and groundwater, multiobjective water resources planning, and optimization of water resource systems. Topics may vary from term to term. Letter grading. Mr. Stoltenbach (F, W, 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 on colloids, microbial response to colloids, transport of colloids in porous media, coagulation, and particle deposition. Consideration of applications to colloidal processes in aquatic environments. Letter grading. Mr. Stenstrom (Sp)

262A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M203A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, chemical thermodynamics, reaction mechanism, and photochemistry; chemical composition and history of Earth's atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere; chemical processes in troposphere and stratosphere; chemical processes; air pollution; chemistry and climate. S/U or letter grading. (W)

262B. Atmospheric Diffusion and Air Pollution. (4) (Same as Atmospheric and Oceanic Sciences M203B.) Lecture, three hours. Nature of sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complexes; atmospheric chemistry, reaction rate 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. Letter grading. (W)
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 (W)

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 (Sp)

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 pollution control, bioremediation, biomass conversion: composting, biogas and bioethanol production. Letter grading. Mr. Stolzenbach (Sp)

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

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

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

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

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

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


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Songwu Lu, Ph.D.
Rupak Majumdar, Ph.D.
Todd Millstein, Ph.D.
Glenn Reinman, Ph.D.

Senior Lecturer
Leon Levine, M.S., Emeritus

Lecturers P. S.O.E.
Paul Eggert, Ph.D.
David Smallberg, M.S.
Adjunct Professors
Alan Kay, Ph.D.
Boris Kogan, Ph.D.
Gerald J. Popek, Ph.D.

Adjunct Associate Professors
Leon Alkalai, Ph.D.
Peter L. Reiher, Ph.D.

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

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

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

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

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

1. The broad scientific and technical skills needed for initial employment and a productive career in a rapidly changing environment to provide (a) a thorough grounding in mathematics and science as a foundation for an understanding of computer science, engineering, and many of the technical applications to which computers are applied, (b) a common core knowledge of the principal areas of computer science (theory, algorithms, data structures, software design, concepts of programming languages, and computer architecture) and an understanding of the fundamentals of one engineering or computer applications discipline, (c) the ability to formulate and solve computer science and engineering problems, including design and analysis, conducting measurements, and evaluating trade-offs of functionality and cost, (d) outstanding skills in programming and good engineering practices of software development, and (e) the ability to use modern design and analysis tools for implementing and evaluating hardware, software, and engineering designs

2. Specialization in preparation for research or engineering practice in computing and the fertile application areas where computing and other technical fields intersect to (a) provide understanding of specialized areas of computer science and in engineering as preparation for research or cross-disciplinary engineering, (b) provide the ability to understand the larger systems goals with the ability to design specifications and integrate separately engineered products into a well-balanced design that meets user needs, and (c) take maximum advantage of the resources of a research university through undergraduate involvement in research with mentoring by faculty researchers and their research associates

3. Professional skills needed for success in teamwork, written and oral communications, an understanding of the societal, economic, and ethical implications of their work, and familiarity with rapidly changing technologies and the necessity for lifelong learning to remain relevant by (a) providing ample individual projects for students to develop and demonstrate knowledge gained, creativity, and written and oral communication skills, (b) providing opportunities for students to develop and demonstrate teamwork, written and oral communications, and to integrate knowledge and

Poster session at the Computer Science department research review.
skills gained from preceding studies through capstone design courses in computer hardware and/or software, (c) providing coverage of ethical and societal issues through discussions in regular courses and a required specialized ethics course, (d) providing familiarity with advanced developments in technology-based courses and a sufficient understanding of the history and technology advances in each area to demonstrate the need for lifelong learning, (e) developing independent study skills to obtain and demonstrate knowledge of state-of-the-art information, and (f) providing an environment that nurtures student involvement and leadership skills by actively supporting student organizations and their projects.

4. A grounding in humanities and social sciences to broaden student perspectives by better understanding student culture and the relationship between engineering and science and other forms of creative thinking, and by developing lifelong interests in nontechnical areas to provide an appreciation of creative thinking of a nonquantitative nature found in the arts and humanities, and a better understanding of the wider culture in which scientists and engineers function most effectively both as citizens and professionals.

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

The computer science and engineering curriculum is also accredited by the Computing Accreditation Commission of ABET, a professional engineering accreditation organization.

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

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

1. Four core courses: Computer Science 31, 32, 33, M51A (or Electrical Engineering M16)

2. Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), 180, 181, Electrical Engineering 10, 102, 103, 110, 110L, 115A, 115AL, 115C, Statistics 110A; 6 laboratory units from Computer Science M152A (or Electrical Engineering M116L) and M152B (or Electrical Engineering M116D); one computer science/electrical engineering elective (excluding Electrical Engineering 100)

3. Four upper division elective courses from the Computer Science Department. Course 199 may normally be taken only as a free elective; however, students may petition for exceptions in extraordinary situations.

4. Chemistry and Biochemistry 20A; Electrical Engineering 1, 2, Physics 1A, 1B, 4AL, 4BL; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61

5. HSSERAS general education (GE) requirements; see Curricular Requirements on page 21 for details. Computer Science and Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185, which may be applied toward either the humanities or social sciences section of the GE requirements.

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

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

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

1. Four core courses: Computer Science 31, 32, 33, M51A (or Electrical Engineering M16)

2. Computer Science 111, 118, 131, 132, M151B (or Electrical Engineering M116C), 161, 180, 181, Statistics 110A; Computer Science 170A or Electrical Engineering 103; 6 laboratory units from Computer Science M152A (or Electrical Engineering M116L) and M152B (or Electrical Engineering M116D). Students who select Electrical Engineering 103 may not receive credit for Mathematics 151A under the technical minor.

3. Two elective upper division computer science courses.

4. A minor or technical support area composed of three upper division courses selected from one of the following areas: astronomy, atmospheric and oceanic sciences, biology, chemical engineering, chemistry and biochemistry, civil and environmental engineering, Earth and space sciences, economics, electrical engineering, information studies, linguistics, management, materials science and engineering, mathematics, mechanical and aerospace engineering, molecular biology, physics.

5. Electrical Engineering 1, 2, Physics 1A, 1B, 4AL, 4BL; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61.

6. HSSERAS general education (GE) requirements; see Curricular Requirements on page 21 for details. Computer Science majors must also select two additional humanities/social sciences courses and one additional life sciences course and are required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185, which may be applied toward either the humanities or social sciences section of...
the GE requirements. Chemistry 20A may be substituted for one of the life sciences courses.

Graduate Study
For information on graduate admission, see Graduate Programs, page 23.
The following introductory information is based on the 2004-05 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the Publications link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.
The Department of Computer Science offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Computer Science and participates in a concurrent degree program with the John E. Anderson Graduate School of Management.

Computer Science M.S.
Course Requirements
Course Requirement. A total of nine courses is required for the M.S. degree, including a minimum of five graduate courses. No specific courses are required, but a majority of both the total number of formal courses and the total number of graduate courses must consist of courses offered by the Computer Science Department.
Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, M105A, 105D, 199.
Breadth Requirement. Candidates for the M.S. in Computer Science must satisfy the computer science breadth requirement by the end of the fourth quarter in graduate residence at UCLA. The requirement is satisfied by mastering the contents of six undergraduate courses in computer science chosen from the following two groups:

Group I: Four required courses or equivalent from Computer Science M51A, 143 or 180, M151B, 181.
Group II: Two required courses or equivalent from Computer Science 111, 112 or 118, 131 or 132, 161, 170A or 174A.
In addition, for each degree students must complete at least one course per quarter for three quarters of Computer Science 201 with grades of Satisfactory.
Competence in any or all courses may be demonstrated in one of three ways:
1. Satisfactory completion of the course at UCLA with a grade of B— or better
2. Satisfactory completion of an equivalent course at another university with a grade of B— or better
3. Satisfactory completion of a final examination in the course at UCLA

Comprehensive Examination Plan. In the comprehensive examination plan, at least five of the nine courses must be 200-series courses. The remaining four courses may be either 200-series or upper division courses. No units of 500-series courses may be applied toward the comprehensive examination plan requirements.
Thesis Plan. In the thesis plan, seven of the nine courses must be formal courses, including at least four from the 200 series, and three may be in the 100 or 200 series. The remaining two courses must be 598 courses involving work on the thesis.

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

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

Course Requirements
The basic program of study for the Ph.D. degree is built around one major field and two minor fields; the major and at least one minor must be in computer science. The major field corresponds to a body of knowledge contained in six courses, at least four of which are graduate courses.
Breadth Requirement. Candidates for the Ph.D. in Computer Science must satisfy the computer science breadth requirement by the end of the fourth quarter in graduate residence at UCLA. The requirement is satisfied by mastering the contents of six undergraduate courses in computer science chosen from the following two groups:

Group I: Four required courses or equivalent from Computer Science M51A, 143 or 180, M151B, 181.
Group II: Two required courses or equivalent from Computer Science 111, 112 or 118, 131 or 132, 161, 170A or 174A.
In addition, for each degree students must complete at least one course per quarter for three quarters of Computer Science 201 with grades of Satisfactory.
Competence in any or all courses may be demonstrated in one of three ways:
1. Satisfactory completion of the course at UCLA with a grade of B— or better
2. Satisfactory completion of an equivalent course at another university with a grade of B— or better
3. Satisfactory completion of a final examination in the course at UCLA
For requirements for the Graduate Certificate of Specialization, see Engineering Schoolwide Programs.

**Written and Oral Qualifying Examinations**

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

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

**Fields of Study**

**Artificial Intelligence**

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

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

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

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

**Computational Systems Biology (formerly Scientific Computing)**

The computational systems biology field, new in name only beginning in 2004, was previously designated as the single specialization in the scientific computing field called biomedical systems/computational biology. As before, this field can be selected as a major or minor field for the Ph.D. in Computer Science.

**Subject Matter and Course Offerings**

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

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

**Computer Networks**

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

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

1. An appropriate model of the computer system under study
2. An adequate (exact or approximate) analysis of the behavior of this model
3. The validation of the model as compared to simulation and/or measurement of the system
4. Interpretation of the analytical results in order to obtain behavioral patterns and key parameters of the system
5. A design methodology

**Resource Allocation**

Many of the issues involved in the consideration of computer networks deal with the allocation of resources among competing demands. In fact, resource allocation is a significant element in most of the technical (and nontechnical) problems we face today.

Most of our resource allocation problems arise from the unpredictability of the demand for the use of these resources, as well as from the fact that the resources are geographically distributed (as in computer networks). The computer networks field encounters such resource allocation problems in many forms and in many different computer system configurations. Our goal is to find allocation schemes that permit suitable concurrency in the use of devices (resources) so as to achieve efficiency and equitable allocation. The use of demand allocation is found to be effective, since it takes advantage of statistical averaging effects. We identify and exploit this averaging effect whenever possible in our system modeling, analysis, and design. This demand multiplexing (sharing of large systems) comes in many forms and is known by names such as asynchronous time division multiplexing, line switching, message switching, store and forward systems, packet switching, frame relay, call switching, and so forth.

**Computer Science Theory**

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

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 elements. The subsystems must be precisely specified and their interactions modeled and thoroughly understood before a system can be fabricated.

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

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

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

1. Fault-tolerant computing involves the design of systems that can continue operation in the presence of faults. This includes errors in specification, operator errors, software faults, and random failures of hardware components.

Design techniques and modeling tools are being studied for several levels of system design, including specification, software fault-tolerance, and fault-tolerance techniques for VLSI.

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

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

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

5. Computer-aided design of VLSI circuits is an active research area which develops techniques for the automated synthesis of large-scale systems. Topics include logic synthesis, physical design, testing, and yield enhancement for various VLSI technologies such as standard cells, gate arrays, field-programmable gate arrays (FPGAs), and multichip modules (MCMs). Other areas of study include a structural theory of the large-scale global optimizations which arise in VLSI CAD.

6. VLSI architectures and implementation is an area of current interest and collaboration between the Electrical Engineering and Computer Science Departments that addresses the impact of large-scale integration on the issues of computer architecture. In addition to detailed studies of these issues there is an active program in the design of MOS large-scale integrated circuits.

Information and Data Management

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

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

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

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 sys-
tems developed today rely on concepts and lessons that have been extracted from years of research on programming lan-
guages, 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 Laboratory.** For investigating knowledge representation sys-
tems, pattern recognition, expert systems, intelligent user agents, planning, problem solving, heuristic search, and related areas

- **Biocybernetics Laboratory.** Emphasizes integrative, interdisciplinary computa-
tional biology and experimentation in life sciences, medicine, physiology, and pharmacology. Laboratory pedagogy involves development and exploitation of the synergistic and methodologic inter-
face between modeling and laboratory data and experimentation, and inte-
grated approaches for solving complex biosystem problems from sparse bio-
data. See http://biocyb.cs.ucla.edu

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

- **Cognitive Systems Laboratory.** For studying systems that emulate human cogni-
tion, especially learning, planning, and reasoning under uncertainty. Topics include causal reasoning, knowledge discovery, knowledge compilation, physical systems diagnosis, and auto-
mated explanation. See http://singapore.cs.ucla.edu

- **Collaborative Design Laboratory.** For investigating methods for effective computer support of small teams involved in design and research

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

- **Concurrent Systems Laboratory.** For inves-
tigating the design, implementation, and evaluation of computer systems that use state-of-the-art technology to achieve both high performance and high reliabil-
ity. Research is often related to multipro-
cessors and multicomputers in the context of general-purpose as well as embedded systems. See http://www.cs. ucla.edu/csd/research/labs/csdl/

- **Data Mining Laboratory.** For extraction of patterns, anomalies, concepts, classifi-
cation rules, and other forms of high-
level relationships that are latent in large commercial and scientific databases. See http://dml.cs.ucla.edu/main.html

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

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

- **Embedded and Reconfigurable System Design Laboratory.** For studying recon-
cfigurable cores in embedded systems that provide the required adaptability and reconfigurability, and the design and CAD aspects of low-power embed-
ded systems. See http://er.cs.ucla.edu

- **High-Performance Internet Laboratory.** For investigating high-performance quality of service (QoS) techniques in the Inter-
et, including QoS routing in Internet domains, QoS fault-tolerant multicast, TCP congestion control, and gigabit net-
.ucla.edu/NRL/hip/

- **Human/Computer Interface Laboratory.** Use of cognitive science concepts to design more reliable user-friendly interfaces with computer and communication systems and the modeling and visualiza-
.ucla.edu/hcip/

- **Internet Research Laboratory.** For explor-
ing the forefront of current Internet archi-
tecture 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 princi-
ples for large-scale self-organizing sys-
tems and their applications to sensor networking. See http://irt.cs.ucla.edu

- **Knowledge-Based Multimedia Medical Distributed Database Systems Labora-
tory.** For developing new methodologies to access multimedia (numeric, text, image/picture) data by content and fea-
ture rather than by artificial keys such as patient ID. See http://kme-ww.cs.
.ucla.edu

- **Laboratory for Embedded Collaborative Systems.** For research on the architec-
tural challenges posed by massively dis-
tributed, large-scale, physically coupled, and usually untethered and small-form-
factor computing systems. Through proto-
type implementations and simulation, such issues as data diffusion protocols, localization, time synchronization, low-
power wireless communications, and self-configuration are explored. See http://lecs.cs.ucla.edu

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

- **Multimedia Systems Laboratory.** For research on all aspects of multimedia: physical and logical modeling of multi-
media objects, real-time delivery of con-
tinuous multimedia, operating systems and networking issues in multimedia systems, and development of multimedia courseware. See http://www.mmssl.
.cs.ucla.edu

- **Parallel Computing Laboratory.** For research in scalable simulation, provid-
ing an efficient lightweight simulation language, as well as tools for large-scale parallel simulation on modern super-
computers. See http://pcl.cs.ucla.edu

- **System Software Laboratory.** For develop-
ing advanced operating systems, dis-
tributed systems, and middleware and conducting research in systems security

- **UCLA Vision Laboratory.** For research in exploring processing of visual informa-
tion to retrieve mathematical models of the environment in order for humans and machines to interact with it. Applications include image-based rendering for vir-
tual reality, archaeology, CAD, guidance of autonomous vehicles, human/com-
puter interaction, visualization, and rec-
.ucla.edu

- **VLSI CAD Laboratory.** For computer-aided design of VLSI circuits and systems. Areas include high-level and logic-level synthesis, technology mapping, physi-
cal design, interconnect modeling and optimization of various VLSI technolo-
gies such as full-custom designs, stand-
ard cells, programmable logic devices (PLDs), multichip modules (MCs), sys-
tem-on-a-chip (SOCs), and system-in-a-
.ucla.edu

- **Wireless Adaptive Mobility Laboratory.** For investigating wireless local-area net-
works and the interaction between wire-
less network layers, middleware, and applications. Activities include protocol development, protocol analysis and sim-
Faculty Areas of Thesis Guidance

**Professors**

Rajive L. Bagrodia, Ph.D. (U. Texas, 1987)
Distributed algorithms, concurrent programming languages, simulation, performance evaluation of distributed systems

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

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

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

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

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

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

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

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

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

Artificial intelligence

Multimedia systems, database systems, data mining

Rafail Ostrovsky, Ph.D. (MIT, 1992)
Cryptography, distributed algorithms, data mining

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

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

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

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

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

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

**Professors Emeriti**

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

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

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

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

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

Leonard Kleinrock, Ph.D. (MIT, 1963)
Computer networks, computer-communication systems, resource sharing and allocation, computer systems modeling, analysis, and design, queueing systems theory and applications, performance evaluation of congestion-prone systems, performance evaluation and design of distributed multiaccess packet-switching systems, wireless networks, mobile computing, and distributed communication systems

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

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

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

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

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

* Also Professor of Medicine

** Member of Brain Research Institute
Associate Professors
Adnan Y. Darwiche, Ph.D. (Stanford, 1993)
Knowledge representation and reasoning under uncertainty with emphasis on Bayesian networks, structure-driven inference algorithms and knowledge-based compilation techniques. Unifying foundation for logical and probabilistic reasoning. Belief revision and causalitability. Applications to model-based diagnosis and reasoning about physical systems
Eliezer M. Gafni, Ph.D. (MIT, 1982)
Computer communication, networks, mathematical programming
David A. Rennels, Ph.D. (UCLA, 1973)
Digital computer architecture and design, fault-tolerant computing, digital arithmetic
Stefano Soatto, Ph.D. (Cal Tech, 1996)
Virtual control system theory, estimation theory, real-time sensory processing and machine interfaces
Yuval Tamar, Ph.D. (UC Berkeley, 1985)
Computer architecture, VLSI
Song-Chun Zhu, Ph.D. (Harvard, 1996)
Computer vision, statistical modeling and computing, vision and visual arts

Assistant Professors
Junghoo (John) Cho, Ph.D. (Stanford, 2002)
Databases, web technologies, information discovery and integration
Petros Faloutsos, Ph.D. (Toronto, 2001)
Computer graphics, computer animation
Edward Kohler, Ph.D. (MIT, 2001)
Operating systems, networking systems
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
Rupak Majumdar, Ph.D. (UC Berkeley, 2003)
Computer-aided verification
Programming languages
Glenn Reinman, Ph.D. (UC San Diego, 2001)
Computer architecture

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

Lecturers P.S.O.E.
Paul Eggert, Ph.D. (UCLA, 1980)
Programming languages, operating systems principles, compilers, Internet
David Smallberg, M.S. (UCLA, 1998)
Object-oriented software development, programming languages, assembly languages, theory applications in computer science

Adjunct Professors
Alan Kay, Ph.D. (Uehata, 1969)
Smalltalk programming language, object-oriented programming, GUI, computers and technology in general
Boris Kogan, Ph.D. (Moscow, Russia, 1962)
Application of multiprocessor systems with massive parallelism to simulation of dynamic phenomena in excitable biological tissues
Gerald J. Popek, Ph.D. (Harvard, 1973)
Privacy and security in information systems, operating system software design, representation for design and evaluation of databases

Adjunct Associate Professors
Leon Alkalai, Ph.D. (UCLA, 1989)
Computer architecture
Peter L. Reiher, Ph.D. (UCLA, 1987)
Optimistic replication, optimistic concurrency control mechanisms for parallel and distributed systems, distributed systems

Lower Division Courses
2. Great Ideas in Computer Science. (4) Lecture, four hours; outside study, eight hours. Broad coverage for liberal arts and social sciences students of computer science theory, technology, and implications, including artificial and neural machine intelligence, computability limits, virtual reality, cellular automata, artificial life, programming languages survey, and philosophical and societal implications. P/NP or letter grading.
351A. Logic Design of Digital Systems. (4) (Same as Electrical Engineering M16.) Lecture, four hours; discussion, two hours; outside study, six hours. Required: Physics 1C. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections, hardware systems and arithmetic algorithms. Error control codes for digital information. Letter grading.

Upper Division Courses

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

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 distributed embedded systems. Topics include design implications of energy and otherwise resource-constrained nodes, network self-configuration and adaptation, localization and time synchronization, applications, and usage issues such as human interfaces, safety, and security. Heavily project based. Letter grading.

117. Computer Networks: Physical Layer. (6) Lecture, four hours; discussion, four hours; outside study, 10 hours. Not open to students with credit for course M171L. Introduction to fundamental data communication concepts underlying and supporting modern networks, with focus on physical and medium 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.

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

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisite: course 32. Structured programming, program specification, program proving, modularity, abstraction data types, composite design, software tools, software control systems, program testing, team programming. 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 enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.
131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 32, 33. Basic concepts in design and use of programming languages, including abstraction, modularity, control mechanisms, types, declarations, syntax, and semantics. Study of several different language paradigms, including functional, object-oriented, and logic programming. Letter grading.

Mr. Eggert, Mr. Millstein (F, W)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 131, 161. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; theory of parsing. Letter grading.

Mr. Eggert, Mr. Palsberg (W)

133. Parallel and Distributed Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 131, 161. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; theory of parsing. Letter grading.

Mr. Eggert, Mr. Palsberg (W)


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


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


Mr. Erengocmez (W, odd years)

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

Mr. Rennells (F, W, Sp)

M512B. Digital Design Project Laboratory. (4) (Same as Electrical Engineering M116D.) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisite: course M51B or Electrical Engineering M116C. Design and implementation of complex digital subsystems using field-programmable gate arrays (e.g., processors, special-purpose processors, device controllers, and input/output interfaces). Students work in teams to develop and implement designs and to document and give oral presentations of their work. Letter grading.

Mr. Rennells, Mr. Tamir (F, W, Sp)

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

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


Mr. Dyer (W)


M171L. Data Communication Systems Laboratory. (2-10) (Same as Electrical Engineering M171L.) Laboratory, four to eight hours; outside study; two to four hours. Recommended preparation: courses M121A, 171. Limited to seniors. Introduction of anal- og-signaling aspects of digital systems and data communications through experience in using con- temporary test instruments to generate and display signals. Hands-on experience with oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem and terminal characteristics, and in- terfaces. Letter grading.

Mr. Gerla (F, W, Sp)

174A. Introduction to Computer Graphics. (4) (Formerly numbered 174.) Lecture, four hours; dis- cussion, one hour; laboratory, two hours. Basic prin- ciples behind modern two- and three-dimensional computer graphics systems, including complete set of steps that modern graphics pipelines use to create realistic images in a real time. How to position and ma- nipulate objects in scene using geometric and cam- era transformations. How to create final image using perspective and orthographic transformations. Basics of modeling primitives such as polygonal models and implicit and parametric surfaces. Basic ideas behind color spaces, illumination models, shading, and tex- ture mapping. Letter grading.

Mr. Faloutsos, Mr. Soatto (F)

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

Mr. Faloutsos, Mr. Soatto (W)

180. Introduction to Algorithms and Complexity. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32, and Mathematics 61 or 113. Designed for junior/senior Computer Science majors. Introduction to design and analysis of algorithms. Design techniques: divide-and-conquer, greedy method, dynamic programming; searching and prototypical algorithms, fundamental data structures and representations; complexity mea- sures: time, space, upper, lower bounds, asymptotic complexity; NP-completeness. Letter grading.

Mr. Gafni, Mr. Meyerson (F, W, Sp)


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

M186A. Introduction to Cybernetics, Biomodel- ing, and Biomedical Computing. (2) (Formerly numbered M196A.) (Same as Biomedical Engineer- ing M186A and Cybernetics M186B.) Lecture, four hours; discussion, one hour; laboratory, two hours. Requisites: Mathematics 31A, 31B, Program in Computing 10A. Strongly recommended for stu- dents with potential interest in biomedical engineer- ing, or related fields at the interface between computer science and medicine. Introduction and survey of topics in cybernetics, bi- modeling, biocomputing, and related bioengineering disciplines. Lectures presented by faculty currently performing research in one of these fields. Some ses- sions include laboratory tours. P/NP grading.

Mr. DiStefano (F)

M186B. Computational Systems Biology: Model- ing and Simulation of Biological Systems. (5) (Formerly numbered M196B.) (Same as Biomedical Engineer- ing M186B, Cybernetics M186B, and Medi- cine M186B.) Lecture, four hours; discussion, one hour; laboratory, two hours. Requisite: Electrical Engi- neering 120 or Mathematics 115A. Introduction to dynamic system modeling, compartmental modeling, and computer simulation methods for studying bio- medical systems. Basics of numerical simulation al- gorithms, translating biomedical models and data into mathematical models and implementing them for simu- lation and analysis. Modeling software exploited for class assignments in P.C. laboratory. Letter grading.

Mr. DiStefano (Sp)

CM120L. Biomedical Systems/Biocybernetics Re- search Laboratory. (2 to 4) (Formerly numbered CM196L.) (Same as Biomedical Engineering CM186L and Cybernetics M186L.) Lecture, two hours; labora- tory, two hours. Requisite: course M186B. Special lab- oratory techniques and experience in biocybernetics research. Laboratory instruments, their use, design, and/or modification for research in life sciences. Spe- cial research hardware, firmware, software. Use of simulation in experimental laboratory. Laboratory au- tomation and safety. Comprehensive experiment de- sign. Radioactive isotopes and kinetic studies. Experimen- tal animals, controls. Concurrently scheduled with course CM226L. Letter grading.

Mr. DiStefano

188. Special Courses in Computer Science. (4) (Formerly numbered 199.) Lecture, four hours; outside study, eight hours. Special topics in computer science for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.
Graduate Courses

210. Computer Science Seminar. (2) Seminar, four hours; outside study, two hours. Designed for graduate computer science students. Seminars on current research activities in computer science may be repeated for credit. SU grading. (F,W,Sp)

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

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


212B. Queueing Applications: Scheduling Algorithms and Queueing Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 212A. Priority queueing. Applications to time-sharing scheduling in computer systems. RB, Round Robin, Round Robin on priority. Queueing networks: definitions; job flow balance; product form solutions — local balance, M/M —; computational algorithms for performance evaluation; basic assumptions; bounds; approximation techniques — diffusion — iterative techniques; applications. Letter grading. Mr. Muntz

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

214. Data Transmission in Computer Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112. Limited to graduate computer science students. Data flow streams: formats, rates, transductions; digital data transmissions via analog signaling in computer communications; media characteristics, systems methodologies, performance analysis: modern design and control. Letter grading. Mr. Muntz

215. Computer Communications and Networks. (4) Lecture, four hours; outside study, eight hours. Requisite: course 112. Resource sharing; computer traffic characteristics; multiplexing; network structure; packet switching and other switching techniques; ARPANET and other computer network elements: network delay and analysis; network design and optimization; network protocols; routing and flow control; measures of service efficiency; database management and local networks; commercial network services and architectures. Optional topics may include error control techniques; modern; SDLC, HDLC, X.25, etc.; protocols and applications: network simulation and measurement; integrated networks; communication processors. Letter grading. Mr. Chu (F)

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

217. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of Internet development history and fundamental principles underlying TCP/IP protocol design. Discussion of current research topics, including multicast routing protocols, multicast transport protocols (e.g., real-time transport protocol, RTP, and SMRT), support for integrated services, World Wide Web, multimedia applications on Internet. 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 courses. Designed for graduate economists and engineering students. Stabilization policies, short- and long-run dynamics and stability analysis; decentralization, coordination in teams; certainty equivalence and stochastic programming; Bayesian approach to price and output rate adjustment. SU or letter grading.

230A. Models of Information and Computation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131, 131. Programming, frameworks, and problem solving; UML and metamodeling; basic information and computation models; axiomatic systems; domain theory; least fixed point theories; well-foundedness condition. Logic: models; expressions, equations, evaluation; combinators; lambda calculus; functional programming. Program models: program derivation and verification using Hoare logic, object models, standard templates, design patterns, frameworks. Letter grading. Mr. Bagrodia, Mr. Parker, Mr. Zaniolo

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

233B. Verification of Concurrent Programs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Formal techniques for verification of concurrent programs. Topics include safety, liveness, program and state assertion-based techniques, theorem-proving in theorem-proving logics, and temporal logic, UNITY, and axiomatic semantics for selected parallel languages. Letter grading. Mr. Bagrodia

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

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

240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 143, 240A. Logical models for data and knowledge representations. Rule-based languages and nonmonotonic reasoning. Temporal queries, spatial queries, and uncertainty in deductive databases and object relational databases (ORDBs). Abstract data types and user-defined condition functions in ORDBs. Data mining algorithms. Semistructured information. Letter grading. Mr. Muntz, Mr. Parker, Mr. Zaniolo

Mr. Cardenas

241B. Pictorial and Multimedia Database Systems. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 241A. Multimedia data: alphanumeric, long text, images/videos, video, and voice. Multimedia information systems, requirements, database design and organization, logical and physical. Search by content and indexing methods. Internet multimedia streaming. Data heterogeneity and distribution. Other topics at discretion of instructor. Letter grading.

Mr. Cardenas

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

Mr. Chu (Sp)


Mr. Chu

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

Mr. Cho (F)

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

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

Mr. Ercegovac, Mr. Tamir (F)

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

Mr. Ercegovac, Mr. Tamir (W)

252A. Arithmetic Algorithms and Processors. (4) Lecture, four hours; outside study, eight hours. Requisite or corequisite: course 251A. Fundamental concepts of computable arithmetic. Design methodology for practical arithmetic hardware. Numerical accuracy and error measures, tool design. Design for critical applications: long-life, real-time, and high-availability systems. Tolerance of design faults: design diversity and fault-tolerant computation. Discussion of applications of a number of important optimization techniques, such as network synthesis, Steiner trees, simulated annealing, and genetic algorithms. Letter grading.

Mr. Ercegovac (F)


Mr. Ercegovac

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

Mr. Chu, Mr. Rennels (Sp)

255A. Distributed Processing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course M51A. Detailed study of various problems in testing and testable designs of VLSI systems. Design for reliability, 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


Mr. Tamir (Sp)

258A. Design of VLSI Circuits and Systems. (4) (Same as Electrical Engineering M216A.) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisite: course M51A or Electrical Engineering M16, and Electrical Engineering 115A. Recommended: Electrical Engineering 115C. LSIVLSI design and application in commercial systems. Fundamental techniques that can be used to implement complex integrated systems on a chip. Letter grading.

Mr. Rennels

258B-M258C. LSI in Computer System Design. (4-4) (Same as Electrical Engineering M216B-M216C.) Lecture, four hours; laboratory, four hours. Requisite: course M258A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. In Progress (M258B) and S/U or letter (M258C) grading.

Mr. Rennels

258E. Foundations of VLSI CAD Algorithms. (4) Lecture, four hours; outside study, eight hours. Preparation: one course in analysis and design of algorithms. Basic theory of combinatorial optimization for VLSI physical layout, including mathematical programming, network flows, matching, greedy and heuristic algorithms, and stochastic methods. Emphasis on hardware application to layout design, physical design of VLSI circuits at high-level phases of layout: partitioning, placement, graph folding, floorplanning, turnpiping, channel and switching routed, 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 (W)

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M51A, 180. Detailed study of various problems in logic-level synthesis of VLSI digital systems, including two-level Boolean network optimization, multilevel Boolean network optimization, technology mapping for standard cell designs and field-programmable gate-array (FPGA) designs; retiming for sequential circuits; and applications of binary decision diagrams (BDDS). Letter grading.

Mr. Cong

259. Advanced Analysis and Design of 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 over both inter- and intra-chip cord circuits, including interconnect capacitance and resistance, lossless and lossy transmission lines, cross-talk and power distribution noise, delay models and power dissipation models, interconnect topology and geometry optimization, and clocking for high-speed systems. Letter grading.

Mr. Cong

259. Current Topics in Computer Science: System Design/Architecture. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in an area of computer science system design in which instructor has developed special proficiency as a consequence of research experience in three hours. Students report on selected topics. May be repeated for credit with topic change. Letter grading.


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

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

M262C. Causal Inference. (4) (Same as Statistics M241.) Lecture, four hours; outside study, eight hours. Requisite: course 112 or equivalent probability theory course. Techniques of using computers to interpret, summarize, and form theories of empirical observations. Mathematical analysis of trade-offs between computational complexity, storage requirements, and precision of computerized models. Letter grading. Mr. Pearl

262Z. Current Topics in Cognitive Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 262A. Additional requisites for each offering announced in advance by department. Theory and implementation of systems which emulate or support human reasoning. Current literature and individual studies in artificial intelligence, knowledge-based systems, decision support systems, computational psychology, and heuristic programming theory. May be repeated for credit with topic change. Letter grading. Mr. Pearl

263A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Introduction to natural language processing (NLP), with emphasis on semantics. Presentation of process models for variety of tasks, including question answering, paraphrasing, machine translation, word-sense disambiguation, narrative and editorial comprehension. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading. Mr. Pearl

263B. Connectionist Natural Language Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 161 or 163 or 263A. Examination of connectionist/ANN architectures designed for natural language processing. Issues include localist vs. distributed representations, variable binding, instantiation and inference via spreading activation, acquisition of language and world knowledge (for instance, via back propagation in PDP networks and competitive learning in self-organizing feature maps), and grounding of symbols in sensory/motor experience. Letter grading. Mr. Dyer (Sp)

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

264A. Automated Reasoning: Theory and Applications. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course 161. Introduction to the theory and practice of automated reasoning using propositional and first-order logic. Topics include syntax and semantics of formal logic; algorithms for logical reasoning, including satisfiability and entailment; syntactic and semantic restrictions on knowledge bases; effect of these restrictions on expressiveness, compactness, and computational tractability; applications of automated reasoning to diagnosis, planning, design, formal verification, and reliability analysis. Letter grading. Mr. Darwiche (F)


267A. Neural Models. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Review of major neurophysiological milestones in understanding brain architecture and processes. Focus on brain theories that are important for understanding that are used in computer vision, image processing (NLP), with emphasis on semantics. Pre-requisite: course 161. Introduction to theory and practice of automated reasoning using propositional and first-order logic. Topics include syntax and semantics of formal logic; algorithms for logical reasoning, including satisfiability and entailment; syntactic and semantic restrictions on knowledge bases; effect of these restrictions on expressiveness, compactness, and computational tractability; applications of automated reasoning to diagnosis, planning, design, formal verification, and reliability analysis. Letter grading. Mr. Darwiche (F)

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 multiset pattern recognition including speed and vision, and inductive robot modeling. Students required to prepare a paper analyzing research in one area of interest. Letter grading. Mr. Vidal

268. Machine Perception. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Fundamental concepts, theories, and applications. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading. Mr. Pearl

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

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

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


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

272. Advanced Discrete Event Simulation and Modeling Techniques. (4) Lecture, four hours; outside study, eight hours. In-depth study in discrete event simulation and modeling techniques, including building valid and credible simulation models, output analysis of systems, comparisons of alternative system configurations. Variance reduction techniques, simulation models of computer systems and manufacturing systems. Letter grading. (Sp)


M276A. Pattern Recognition and Machine Learning. (4) (Formerly numbered 276A.) (Same as Statistics M231.) Lecture, three hours. Designed for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are used in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering, complexity (VC-dimension, MDL, AIC), PCA, MDS, SVM, boosting, S/U or letter grading. Mr. Zhu

276B. Structured Computer Vision. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Methods for computer processing of image data. Systems, concepts, and algorithms for image analysis, radiologic and robotic applications. Letter grading. Mr. Kling

278. Seminar: to be arranged. Review of major research in artifical intelligence. Students required to prepare a paper analyzing research in one area of interest. Letter grading.
M282B. Cryptographic Protocols. (4) (Formerly numbered 282B.) (Same as Mathematics M209B.) Lecture, four hours; outside study, eight hours. Prerequisite: 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; proofs of knowledge; and notions of security for public-key encryption, including chosen-plaintext security; secure multiparty computation; dealing with dynamic adversary; noninteractivity and composability of secure protocols; software protection; threshold cryptography; identity-based cryptography; private information retrieval; protection against man-in-the-middle attacks; voting protocols; identification protocols; and lower bounds on use of cryptographic primitives, software obfuscation. May be repeated for credit with topic change. Letter grading. Mr. Ostrovsky (W)

M284A-284ZZ. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Prerequisite: course 180. Additional requisites for each offering announced in advance by departed. Selections from design, analysis, optimization, and implementation of algorithms; computational complexity and general theory of algorithms; algorithms for particular applica- tion areas. Subtitles of some current sections: Princi- ples of Design and Analysis (280A); Distributed Algo- rithms (280D); Graphs and Networks (280G). May be repeated for credit. Special lab fee. Classification of decidable and undecidable problems, "easy" and "hard" problems, PTIME/NP- TIME. Letter grading. Ms. Greibach, Mr. Parker

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Recommended prerequisite: course 181. Finite-state machines, trans- ducers, and their generalizations; regular expres- sions, transduction expressions, realizability, decom- position, synthesis, and design considerations; topics in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system model- ing, and simulation. Letter grading. Mr. Carla Klinger

M282A. Cryptography. (4) (Formerly numbered 282A.) (Same as Mathematics M209A.) Lecture, four hours; outside study, eight hours. Introduction to the- ory of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hard- ness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public- key and private-key encryption, secret-sharing, mes- sage authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, key-agree- ment, contract signing, and two-party secure computa- tion with stateless biometric data. Letter grading. Mr. Ostrovsky (W)

M289A. Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomization, such as probability theory, Markov chains, random walks, and probabilistic method. Applications to randomized algorithms in data structures, graph theory, computa- tional geometry, number theory, and parallel and dis- tributed systems. Letter grading. Mr. DiStefano

289RA. Advanced Modeling Methodology for Dy- namic Biomedical Systems. (4) (Same as Biomed- ical Engineering M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Prerequisite: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharma- cological, and chemical processes, including network interactions, feedback systems, and computer simulation of system, multicompartimental, noncompartmental, and input/output models, linear and nonlinear. Emphasize on model applications, limitations, and rele- vance in biomedical sciences and other limited data environments. Problem solving in PC laboratory. Letter grading. Mr. DiStefano (F)

M296B. Optimal Parameter Estimation and Exper- iment Design for Biomedical Systems. (4) (Same as Biomedical Engineering M296C and Medi- cine M270E.) Lecture, four hours; outside study, eight hours. Prerequisite: course M296A or course M282A or course M282B. Optimal methods for biological and chemical processes, including model parameter estimation algorithms for fitting dy- namic systems models to biomedical data. Model dis- crimination methods. Theory and algorithms for de- sign of optimal experiments and data quantifying models, with special focus on optimal sampling schedule design for kinetic models. Explo- ration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano

M296C. Advanced Topics and Research in Bio- medical Systems Modeling and Computing. (4) (Same as Biomedical Engineering M296C and Medi- cine M270E.) Lecture, four hours; outside study, eight hours. Prerequisite: course M296A. Recommended: course M296B. Research techniques and experience on special topics involving models, modeling meth- ods, and modeling in biomedical and biological and medical sciences. Review and critique of literature. Research problem solving and formulation. Approaches to solutions. Individual M.S.- and Ph.D-level project training. Letter grading. Mr. DiStefano

M296D. Introduction to Computational Cardiolo- gy. (4) (Same as Biomedical Engineering M296D.) Lecture, four hours; outside study, eight hours. Re- quirements: course M196B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological processes. Ionic models of action potent- ial (AP). Theory of AP propagation in 1D and 2D car- diac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational sta- bility. Letter grading. Mr. DiStefano, Mr. Kogan (Sp)

296. Research Seminar: Computer Science. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate computer science students. Discussion of advanced topics and current research in algorithmic processes that describe and transform information; theory, analysis, design, effi- ciency, implementation, and application. May be re- peated for credit. S/U grading. (F,W,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as a teaching assistant, asso- ciate, or fellow. Teaching apprentice under active guidance and supervision of a regular faculty mem- ber responsible for curriculum and instruction at the University. May be repeated for credit. S/U grading. (F,W,Sp)
995. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, six hours. Limited to graduate Computer Science Department students. Seminar on communication of computer science materials in classroom: preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading.

995B. Teaching with Technology. (2) Seminar, two hours; outside study, four hours. Limited to graduate Computer Science Department teaching assistants. Seminar for teaching assistants covering how technology can be used to aid instruction in and out of classroom. S/U grading.

497D-497E. Field Projects in Computer Science. (4-4) Fieldwork, to be arranged. Students are divided into teams led by instructor; each team is assigned an external company or organization which they investigate as a candidate for possible computerization, submitting a team report of their findings and recommendations. In Progress (497D) and S/U or letter (497E) grading. Mr. Cardenas

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

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

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

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

599. Research for and Preparation of Ph.D. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate computer science students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. S/U grading.

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**Electrical Engineering**

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Professors Emeriti
Frederick G. Allen, Ph.D.
Francis F. Chen, Ph.D. (Research Professor)
Robert H. Cottrell, Ph.D.
Richard E. Mortensen, Ph.D.
Frederick W. Schott, Ph.D.
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Donald M. Wiberg, Ph.D.
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Associate Professors
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Lieve Vandenberghe, Ph.D.
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Assistant Professors
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Giorgio Franceschetti, Ph.D.
Brian H. Kolner, Ph.D.
Joel Schulman, Ph.D.
Pyotr Y. Ufimtsev, Ph.D.

Adjunct Associate Professor
Bijan Houshmand, Ph.D.

Adjunct Assistant Professor
Charles Chien, Ph.D.

**Scope**

The Electrical Engineering Department emphasizes teaching and research in the fields of communications and telecommunication, control systems, electromagnetics, embedded computing systems, engineering optimization/operations research, integrated circuits and systems, microelectromechanical systems/nanotechnology (MEMS/nano), photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. In each of these fields, the department has state-of-the-art research programs exploring exciting new concepts and developments. Undergraduate students receive a B.S. degree in Electrical Engineering. Graduate research and training programs leading to the M.S. and Ph.D. degrees are also offered.

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

**Department Mission**

In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the Electrical Engineering Department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental and cutting-edge technical knowledge in electrical engineering to serve California, the nation,
and the world, (2) pursue creative research and new technologies in electrical engineering and across disciplines in order to serve the needs of industry, government, society, and the scientific community by expanding the body of knowledge in the field, (3) develop partnerships with industrial and government agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

Undergraduate Program Objectives

The ABET-accredited electrical engineering curriculum gives an excellent background for either graduate study or employment. In consultation with its constituents, the Electrical Engineering Department has set its educational objectives as follows: (1) fundamental knowledge to equip undergraduate students with knowledge of the fundamentals of electrical engineering, with exposure to both analytical techniques and experimentation, (2) specialization to provide undergraduate students with the opportunity to specialize in electrical engineering, biomedical engineering, and computer engineering, (3) design skills to equip undergraduate students with problem-solving skills and to help them develop the ability to solve engineering problems by participating in creative design projects, (4) professional skills to equip graduate students with communication and leadership skills within an environment that nurtures ethical behavior, and (5) self-learning to encourage undergraduate students to pursue self-learning and personal development experiences in a rigorous program and through participation in undergraduate research opportunities.

Electrical Engineering B.S.

The Major

Course requirements are as follows (190 minimum units required):

1. One engineering breadth course from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A)

2. Electrical Engineering 10, M16 (or Computer Science M51A), 101, 102, 103, 110, 110L, 113, 114D, 115A, 115AL, 121B, 131A, 132A, 141, 161, 172, Mathematics 113 or 132, Mechanical and Aerospace Engineering 182A

3. Five major field elective courses (18 units minimum) selected from those offered by the Electrical Engineering Department. Of the five courses, one laboratory course (4 units) and one design course (4 units) are required. With approval of the adviser, two may be selected from courses related to electrical engineering in other departments

4. Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31, 32; Electrical Engineering 1, 2; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details. Electrical Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185, which may be applied toward either the humanities or social sciences section of the GE requirements

Biomedical Engineering Option

Course requirements are as follows (201 minimum units required):


2. Life Sciences 1 (satisfies HSSEAS GE life sciences requirement), 2, 3

3. Three technical electives, including one course selected from Electrical Engineering 115B, 115C, 142, 172; the remaining two courses may be selected from the above list and/or from Biomedical Engineering C101, CM102, CM103, Computer Science M186B, CM186L, Electrical Engineering 176

4. Chemistry and Biochemistry 20A; Computer Science 31, 32, 33; Electrical Engineering 1, 2; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details. Electrical Engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185, which may be applied toward either the humanities or social sciences section of the GE requirements

Computer Engineering Option

Course requirements are as follows (190 minimum units required):

1. One engineering breadth course from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A)

2. Computer Science 111, 180, Electrical Engineering 10, M16 (or Computer Science M51A), 101, 102, 103, 110, 110L, 113, 115A, 115AL, 115C, M116C (or Computer Science M151B), M116D (or Computer Science M152B), M116L (or Computer Science M152A), 121B, 131A, 132A, 132B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL

3. Four technical elective courses, one of which must be Electrical Engineering 132A or either Computer Science 118 or Electrical Engineering 132B. The remaining three courses must be upper division electrical engineering or computer science courses, and at least three of the four must be from the Electrical Engineering Department

4. Chemistry and Biochemistry 20A; Computer Science 31, 32, 33; Electrical Engineering 1, 2; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 4AL, 4BL

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details. Electrical engineering majors are also required to satisfy the ethics and professionalism requirement by completing one course from Engineering 95 or 183 or 185, which may be applied toward either the humanities or social sciences section of the GE requirements

Departures from the stated requirements are possible, and students who wish to follow programs that cannot be accommodated within these requirements may prepare, in consultation with their advisers, proposals for consideration by the department. Variations are approved if the overall program has a well-defined educational objective and is substantially equivalent to the existing curriculum in breadth and depth.
Graduate Study
For information on graduate admission see Graduate Programs, page 23.

The following introductory information is based on the 2003-04 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 500-level courses not applicable toward the minimum course requirement. A majority of the courses must be in or related to electrical engineering and belong to one of the specialized major fields described below.

Undergraduate Courses. Lower and upper division undergraduate courses required for any of the B.S. options in Electrical Engineering cannot be applied toward graduate degrees.

In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, M105A, 105D, 199.

Communications and Telecommunications
Requisite: B.S. degree in Engineering or equivalent.

Minimum Course Requirements. Nine 4-unit courses, of which at least six must be graduate courses.

Thesis Plan. Electrical Engineering 230A, 232A; two additional 200-level electrical engineering courses in the communications and telecommunications engineering area; three or more courses, of which at least two must be 200-level electrical engineering courses, subject to the approval of the student’s adviser. Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses.

Comprehensive Examination Plan. Electrical Engineering 230A, 232A; two additional 200-level electrical engineering courses in the communications and telecommunications engineering area; five or more courses, of which at least two must be 200-level electrical engineering courses, subject to the approval of the student’s adviser.

Control Systems
Requisite: B.S. degree in Electrical Engineering or equivalent.

Thesis Plan. Seven graduate-level courses, of which at least five must be selected from the list of courses covering the control systems fundamentals, and a thesis. The remaining courses are subject to the approval of the student’s adviser. In addition, 8 units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis.

Comprehensive Examination Plan. Nine courses, of which seven must be graduate courses and at least five must be selected from the list of courses covering the control systems fundamentals. The remaining courses are subject to the approval of the student’s adviser.


Electromagnetics
Requisite: B.S. degree in Electrical Engineering or equivalent.

Thesis Plan. Eight units (two courses) of Electrical Engineering 598 must be taken to cover the research work and preparation of the thesis. Both 598 courses count toward the minimum of nine courses, but only one can count toward the requirement of five graduate-level courses. A minimum of four graduate courses is to be selected from the Group II list.

The remaining 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.
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)

**Requisite.** B.S. degree in Electrical Engineering, Mechanical Engineering, Physics, or equivalent.

**Minimum Course Requirements.** At least nine graduate and upper division courses (36 units) must be completed in graduate standing. At least six courses (24 units) must be graduate 200-level courses. All courses in Group I (14 units) must be completed, and at least one course (4 units) must be selected from Group II. The remaining 18 units may be free electives, but 12 units must be at the graduate level.

**Comprehensive Examination Plan.** Course requirements listed above and the comprehensive examination must be completed.

**Thesis Plan.** Course requirements listed above and a thesis, which must be reviewed by a committee of at least three faculty members who hold regular professorial appointments at the University (no adjunct or visiting professors), must be completed. A maximum of 8 units (two courses) of Electrical Engineering 598 may be applied as free electives, but only 4 units (one course) may be applied as one of the six required graduate-level courses. Thesis-plan students who complete only 4 units of course 598 are required to complete four elective courses (16 units), at least two of which must be graduate-level courses. Thesis-plan students who complete 8 units of course 598 are required to complete three elective courses (12 units), at least two of which must be graduate-level courses.

Group I: Electrical Engineering M150, M150L, M250A, M250B.

Group II: Mechanical and Aerospace Engineering 281, 284.

**Free Electives.** All 100- and 200-level courses are acceptable as free electives subject to the approval of the faculty adviser and the chair of the MEMS/nanotechnology major field. Since the field of MEMS/nanotechnology is broadly applicable, students may take these courses from any of the other major fields in electrical engineering, as well as those fields of particular relevance to MEMS/nanotechnology that are outside the Electrical Engineering Department (e.g., mechanical engineering, materials science, bioengineering, chemical engineering, chemistry, physics). Undergraduate core courses may not be applied as free electives. An undergraduate course that is a requisite for a graduate course may not be taken after the graduate course.

Photonics and Optoelectronics

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

**Thesis Plan.** Electrical Engineering 270, 271, either 272 or 273 or 274, 598 (twice), and four additional courses, of which at least one must be a 200-level course.

**Comprehensive Examination Plan.** Electrical Engineering 270, 271, either 272 or 273.
or 274, and six additional courses, of which at least two must be 200-level courses.

Additional Courses. With a few exceptions, all 100- and 200-level courses in the UCLA General Catalog are acceptable subject to the approval of the adviser. The exceptions are the following courses (which are not acceptable for any M.S. program in Electrical Engineering): (1) all school undergraduate core courses and (2) all department undergraduate core courses. Consult the departmental adviser for lists of the courses.

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

Thesis Plan. Electrical Engineering M185, 285A, 285B, 598 (twice), and four additional courses from the list below. Of these, at least two must be in the 200 series and at least one must be in electrical engineering. If Electrical Engineering M185 was taken as an undergraduate, it may be replaced by any engineering course on the list below.

Comprehensive Examination Plan. Electrical Engineering M185, 285A, 285B, and six additional courses from the list below. Of these, at least three must be in the 200 series and at least one must be in electrical engineering. Of the remainder, at least one other course must be in engineering. If Electrical Engineering M185 was taken as an undergraduate, it may be replaced by any course on the list below. Other courses may be substituted with the consent of the department adviser.


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 238 (in solid-state electronics), with the remaining courses from graduate courses and those upper division courses that are not required for the B.S. degree in Electrical Engineering, with approval of the graduate adviser.

Comprehensive Examination Plan

Communications and Telecommunications
A written comprehensive examination is administered by the communications and telecommunications field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the communications and telecommunications field.

Control Systems
A written comprehensive examination, administered by a three-person committee chaired by a member of the controls field committee, must be taken during the last quarter of study toward the M.S. degree. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Electromagnetics
A common six- to eight-hour comprehensive examination is offered once a year to students in this M.S. program. The examination must be taken during the academic year at the end of which students are expected to graduate. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Embedded Computing Systems
Students are required to pass a written examination scheduled by the embedded computing systems field chair to be concurrent with the Ph.D. preliminary examination.

Engineering Optimization/Operations Research
Students take a common written examination during their last quarter of coursework. The examination is normally offered at the end of Fall and Spring Quarters. In case of failure, students may be reexamined once with the consent of the graduate adviser.
Integrated Circuits and Systems

The comprehensive examination plan is not offered.

Microelectromechanical Systems/ Nanotechnology

Students are required to pass a written examination scheduled by the microelectromechanical systems/nanotechnology (MEMS/nano) field chair to be concurrent with the Ph.D. preliminary examination.

Photonics and Optoelectronics

Consult the department. In case of failure of the comprehensive examination, students may be reexamined once with the consent of the graduate adviser.

Plasma Electronics

Consult the department. The majority of M.S. candidates proceed to the Ph.D. The Ph.D. qualifying examination may be taken to satisfy the M.S. comprehensive examination requirement.

Signal Processing

A written comprehensive examination is administered by the signal processing field committee. In case of failure, students may be reexamined once with the consent of the graduate adviser. The examination may be given as part of the written Ph.D. preliminary examination in the signal processing field.

Solid-State Electronics

The comprehensive examination plan is not offered.

Thesis Plan

Consult the department for information on the thesis plan for the areas of communications and telecommunications, control systems, electromagnetics, engineering optimization/operations research, photonics and optoelectronics, and plasma electronics.

Embedded Computing Systems

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted concurrently with the coursework.

Integrated Circuits and Systems

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted in the Integrated Circuits and Systems Laboratory concurrently with the coursework.

Microelectromechanical Systems/ Nanotechnology

Students are expected to find a faculty adviser to direct a research project that culminates in an M.S. thesis. The thesis research must be conducted concurrently with the coursework.

Signal Processing

A thesis must be completed under the direction of a faculty adviser.

Solid-State Electronics

A thesis is required. Consult the department for details.

Electrical Engineering Ph.D.

Major Fields or Subdisciplines

Communications and telecommunications; control systems; electromagnetics; embedded computing systems; engineering optimization/operations research; integrated circuits and systems; microelectromechanical systems/nanotechnology (MEMS/nano); photonics and optoelectronics; plasma electronics; signal processing; solid-state electronics.

Course Requirements

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

Written and Oral Qualifying Examinations

The written qualifying examination is known as the Ph.D. preliminary examination in HSSEAS. After mastering the body of knowledge defined in the major field, students take a preliminary examination in the major field. The examination typically consists of both a written part and an oral part, and students pass the entire examination and not in parts. The oral part does not exceed two hours and in some major fields is not required at all. Students who fail the examination may repeat it once only, subject to the approval of the major field committee. The major field examination, together with the three courses in each of the two minor fields, should be completed within six quarters after admission to the Ph.D. program.

After passing the written qualifying examination described above, students take the University Oral Qualifying Examination, which should occur within three quarters after completing the written examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

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

Fields of Study

Communications and Telecommunications

Communications and telecommunications research is concerned with communications, telecommunications, networking, and information processing principles and their engineering applications. Communications research includes satellite, spread spectrum, and digital communications systems. Fast estimation, detection, and optimization algorithms and processing techniques for communications, radar, and VLSI design are studied. Research is conducted in stochastic modeling of telecommunications engineering systems, switching, architectures, queuing sys-
systems, computer communications networks, local-area/metropolitan-area/long-haul communications networks, optical communications networks, packet-radio and cellular radio networks, and personal communications systems. Research in networking also includes studies of processor communications and synchronization for parallel and distributed processing in computer and sensor network systems. Several aspects of communications networks and processing systems are thoroughly investigated, including system architectures, protocols, performance modeling and analysis, simulation studies, and analytical optimization. Investigations in information theory involve basic concepts and practices of channel and source coding. Significant multidisciplinary programs including sensing and radio communication networks exist.  

Control Systems  
Faculty and students in the control systems field conduct research in control, estimation, filtering, and identification of dynamic systems, including deterministic and stochastic, linear- and nonlinear-, and finite- and infinite-dimensional systems. Topics of particular interest include adaptive, distributed, nonlinear, optimal, and robust control, with applications to autonomous systems, smart structures, flight systems, microelectronics, microelectromechanical systems, and distributed networks.  

Electromagnetics  
Research in electromagnetics is conducted on novel integrated three-dimensional microwave and millimeter wave circuits, components, and systems, printed antennas, wireless and personal communications, fiber optics, integrated optics and photonic bandgap wave-guiding structures, left-handed transmission structures, antenna theory and design, satellite antennas, smart antennas and materials, antennas and biological tissue interactions, modern antenna near field measurement techniques, microwave holography and antenna diagnostics, radar cross section, multiple scattering, genetic algorithms, ultra wideband radar, novel time domain methods in microelectromechanics, advanced EM numerical techniques, and parallel computational techniques.  

Embedded Computing Systems  
Faculty in the embedded computing systems field conduct research in areas including processor architectures and VLSI design methodologies for real-time embedded systems in application domains such as cryptography, digital signal processing, algebra, wireless and high-speed communications, mobile and wireless multimedia systems, distributed wireless sensor networks, power-aware computing and communications, quality of service, quantum and nanoelectronic computation, quantum information processing, fault-tolerant computation, combinatorics and information theory, advanced statistical processing, adaptive algorithms, dynamic circuits to implement configurable computing systems, low-power processor and system design, multimedia and communications processing, and all techniques for leveraging instruction-level parallelism.  

Engineering Optimization/Operations Research  
Engineering optimization/operations research is conducted in optimization theory, including linear and nonlinear programming, convex optimization and engineering applications, numerical methods, nonconvex programming, and associated network flow and graph problems. Another area of study is that of stochastic processes, including renewal theory, Markov chains, stochastic dynamic programming, and queuing theory. Applications are made to a variety of engineering design problems, including communications and telecommunications.  

Integrated Circuits and Systems  
Students and faculty in integrated circuits and systems (IC&S) are engaged in research on communications and RF integrated circuit design; analog and digital signal processing microsystems; integrated microprocessors, microelectromechanical systems, and associated low-power microelectronics; reconfigurable computing systems; and multimedia and communications processors. Current projects include wireless transceiver integrated circuits, including RF and baseband circuits; high-speed data communications integrated circuits; A/D and D/A converters; networking electronics; distributed sensors with wireless networking; and digital processor design. M.S. and Ph.D. degrees require a thesis based on an ongoing IC&S project and full-time presence on campus. More information is at http://www.ICSL.ucla.edu.  

Microelectromechanical Systems/ Nanotechnology  
The microelectromechanical systems/nanotechnology (MEMS/nano) program is one of the fastest growing research programs in the school, with faculty and student participation from the Departments of Electrical Engineering, Mechanical and Aerospace Engineering, Materials Science and Engineering, Chemical 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, electromagnetic, computer engineering, and control systems. MEMS/nano research at UCLA emphasizes the design, fabrication, and physics of sensors, actuators, and systems on a nanometer to millimeter scale. Research project areas include free-space micro optics (MOEMS), biology and medicine (BioMEMS), neuroengineering, advanced circuit integration with MEMS, reconfigurable electromagnetic systems (RF MEMS, millimeter wave devices, antennas), fluid dynamics, and distributed sensor and actuator networks.  

Photonics and Optoelectronics  
The photonics and optoelectronics group conducts research on photonic and optoelectronic devices, circuits, and systems. Target applications include but are not limited to telecommunication, data communication, phased array antenna systems, radar, CATV and HFC networks, and biomedicine. Among technologies being developed are nonlinear optical devices, ultrafast photodetectors and modulators, infrared detectors, mode-locked lasers, photonic bandgap devices, DWDM, CDMA, true time delay beam steering, temporal manipulation techniques and data conversion, digital and analog transceivers, optical MEMS, and biomedical sensors. Laboratory facilities house the latest technology in lasers, optical measurements, Gbit/s bit error rate testing, and millimeter wave optoelectronic characterization. UCLA photonics hosts several national research centers including the DARPA Consortium for Optical A/D System Technology (COAST), the Navy MURI Center on RF Photonics, and the Army MURI Center on Photonic Bandgap Research. The group is a member of the Optoelectronic Industry Development Association (OIDA).
Plasma Electronics

Plasma electronics research is concerned with a basic understanding of both inertially confined and magnetically confined fusion plasmas, as well as with the applications of plasma physics in areas such as laser plasma accelerators, ion beam sources, plasma-materials processing, and free-electron lasers. Extensive laboratory facilities are available, including high-power lasers and microwave and millimeter wave sources and detectors, a state-of-the-art laser and beam physics laboratory for advanced accelerator studies, and large quiescent low-density plasmas for nonlinear wave studies. In addition, experiments are conducted at a variety of national laboratories.

Signal Processing

Signal processing encompasses the techniques, hardware, algorithms, and systems used to process one-dimensional and multidimensional sequences of data. Research being conducted in the signal processing group reflects the broad interdisciplinary nature of the field today. Areas of current interest include analysis, synthesis, and coding of speech signals, video signal processing, digital filter analysis and design, multirate signal processing, image compression, adaptive filtering, communications signal processing, equalization techniques, synthetic aperture radar remote sensing, signal processing for hearing aids, auditory system modeling, automatic speech recognition, wireless communication, digital signal processor architectures, and the characterization and analysis of three-dimensional time-varying medical image data. The M.S. program includes a thesis project or a comprehensive examination.

Solid-State Electronics

Solid-state electronics research involves studies of new and advanced devices with picosecond switching times and high-frequency capabilities up to submillimeter wave ranges. Topics being investigated are hot electron transistors, quantum devices, heterojunction bipolar transistors, HEMTs, and MESFETs, as well as more conventional scaled-down MOSFETs, SOI devices, bipolar devices, and photovoltaic devices. The studies of basic materials, submicron structures, and device principles range from Si, Si-Ge, Si-Silicides, and III-V molecular beam epitaxy to the modeling of electron transport in high fields and short temporal and spatial scales. Research in progress also includes fabrication, testing, and reliability of new types of VLSI devices and circuits.

Facilities and Programs

Computing Resources

Students and faculty have access to a modern networked computing environment that interconnects UNIX workstations as well as Windows and Linux PCs. These machines are provided by the Electrical Engineering Department; most of them operate in a client-server mode, but stand-alone configurations are supported as well. Furthermore, this network connects to mainframes and supercomputers provided by the Henry Samueli School of Engineering and Applied Science and the Office of Academic Computing, as well as off-campus supercomputers according to need. The rapidly growing department-wide network comprises about 500 computers. These include about 200 workstations from Sun, HP, and SGI, and about 300 PCs, all connected to a 100 Mbit/s network with multiple parallel T3 lines running to individual research laboratories and computer rooms. The server functions are performed by several high-speed, high-capacity RAID servers from Network Appliance and IBM which serve user directories and software applications in a unified transparent fashion. All this computing power is distributed in research laboratories, computer class-rooms, and open-access computer rooms.

Center for High-Frequency Electronics

The Center for High-Frequency Electronics has been established with support from several governmental agencies and contributions from local industries. A goal of the center is to combine, in a synergistic manner, five new areas of research. These include (1) solid-state millimeter wave devices, (2) millimeter systems for imaging and communications, (3) millimeter wave high-power sources (gyrotrons, etc.), (4) GaAs gigabit logic systems, and (5) VLSI and LSI based on new materials and structures. The center supports work in these areas by providing the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations into new electronic devices. Students, both graduate and undergraduate, receive training and instruction in a unique facility. The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different interdependent fields. The Electrical Engineering Department, other depart-
ments within UCLA, and local universities (such as Cal Tech and USC) have begun to combine and correlate certain research programs as a result of the formation of the center. Students and faculty are encouraged to become active in using the center’s facilities, attending its seminars, and participating in innovative new research programs. For more information, see http://chfe.ee.ucla.edu.

Circuits Laboratories
The Circuits Laboratories are equipped for measurements on high-speed analog and digital circuits and are used for the experimental study of communication, signal processing, and instrumentation systems. A hybrid integrated circuit facility is available for rapid mounting, testing, and revision of miniature circuits. These include both discrete components and integrated circuit chips. The laboratory is available to advanced undergraduate and graduate students through faculty sponsorship on thesis topics, research grants, or special studies.

Electromagnetics Laboratories
The Electromagnetics Laboratories involve the disciplines of microwaves, millimeter waves, wireless electronics, and electromechanics. Students enrolled in microwave laboratory courses, such as Electrical Engineering 164AL and 164BL, special projects classes such as Electrical Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: (1) integrated microwave circuits and antennas, (2) integrated millimeter wave circuits and antennas, (3) numerical visualization of electromagnetic waves, (4) electromagnetic scattering and radar cross-section measurements, and (5) antenna near-field and diagnostics measurements.

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

Photonics and Optoelectronics Laboratories
In the Laser Laboratory students study the properties of lasers and gain an 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 tabletop terawatt (T3) 400fs laser system that can be operated in either a single or dual frequency mode for laser-plasma interaction studies. Diagnostic equipment includes a ruby laser scattering system, a streak camera, and optical spectrographs and multichannel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing. The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focussable 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 crystalization study, (5) thin film and characterization equipment, (6) deep-level transient spectroscopy instruments, (7) computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, (8) low-temperature facilities for material and device physics studies in cryogenic temperatures, (9) optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, (10) characterization equipment for high-speed devices, including (11) high magnetic field facilities for magnetotransport measurement of heterostructures.

The laboratory facilities are available to faculty, staff, and graduate students for their research.

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

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

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

**Autonomous Intelligent Networked Systems (AINS) Laboratory**

The objectives of the Autonomous Intelligent Networked Systems (AINS) Laboratory, under the direction of Professor Izhak Rubin, are to carry out research investigations and testbed demonstrations of autonomously controlled ad hoc wireless network systems. Current topics of research and development include: use of unmanned airborne and ground vehicles (UAVs and UGVs) to aid in mobile wireless networking; development of cross-layer MAC and network layer protocols for UV-aided multi-tier Qos based networks; Integrated System Management (ISM) for combined communications, maneuvering, and sensing networks; power control and MIMO driven medium access control (MAC) protocols; robust routing and flow/congestion control and performance management mechanisms for ad hoc wireless networks; hybrid analytical statistical simulations of multi-tier wireless networks; wireless home networks; architectures, protocols, and controls. Joint development works include the incorporation of: sensor network systems (Professor Mani B. Srivastava), MIMO radio systems (Professor Babak Daneshrad), and antenna systems (Professor Yahya Rahmat-Samii).

**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 U., Taiwan, 1979)  
High-speed semiconductor (GaAs, InP, and Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications

Harold R. Fetterman, Ph.D. (Cornell, 1968)  
Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state millimeter wave structures and systems, biomedical applications of lasers

* Also Professor of Mathematics

Michael P. Fitz, Ph.D. (USC, 1989)  
Physical layer communication theory and implementation with applications in wireless systems

Warren S. Grundfest, M.D., FACS (Columbia U., 1980)  
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms

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

Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)  
Operations research, mathematical programming, nonconvex programming, applications of mathematical programming to engineering and engineering/economic systems

Rajeev Jain, Ph.D. (Katholieke U., Leuven, Belgium, 1985)  
Design 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

Nhan Levan, Ph.D. (Monash U., Australia, 1966)  
Control systems, stability and stability, errors in dynamic systems, signal analysis, wavelets, theory and applications

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

Warren B. Mori, Ph.D. (UCLA, 1987)  
Laser and charged particle beam-plasma interactions, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics

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

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

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

† Also Professor of Physics
Satellite communications antennas, personal communication antennas including human interactions, antennas for remote sensing and radio astronomy applications, advanced numerical and genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory

Behzad Razavi, Ph.D. (Stanford, 1992)
Analog, RF, and mixed-signal integrated circuit design, dual-standard RF transceivers, phase-locked systems and frequency synthesizers, A/D and D/A converters, high-speed data communication circuits

Vwani P. Roychowdhury, Ph.D. (Stanford, 1970)
Telecommunications and computer communications systems and networks, mobile wireless networks, multimedia IP networks, UAV/LPV-guided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering

Henry Samueli, Ph.D. (UCLA, 1980)
VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design

Ali H. Sayed, Ph.D. (Stanford, 1992)
Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

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

John D. Villasenor, Ph.D. (Stanford, 1989)
Communications, signal and image processing, configurable computing systems, and design environments

Chandr 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-temperature noise

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoelectronics and optoelectronics, nano and molecular devices, MBE and superlattices, microwave and millimeter electronics, quantum electronics, quantum information

Control systems, modeling and control of nonlinear distributed-parameter systems with applications to micro-opto-electromechanical systems, micro and nano manipulation systems, coordination and control of multiple microspacecraft in formation

Alan N. Willson, Jr., Ph.D. (Syracuse, 1967)
Theory and application of digital signal processing including VLSI implementations, digital filter design, nonlinear circuit theory

Jason C.S. Woo, Ph.D. (Stanford, 1987)
Solid-state technology, CMOS and bipolar device/circuit optimization, novel device design, modeling of integrated circuits, VLSI fabrication

Ming C. Wu, Ph.D. (UC Berkeley, 1968)
MEMS, micro-opto-electromechanical systems (MOEMS), optoelectronics, RF photonics, optical communications

Eli Yablonovitch, Ph.D. (Harvard, 1972)
Optoelectronics, high-speed optical communications, photonic integrated circuits, photonic crystals, 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

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

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

Gabor C. Temes, Ph.D. (U. Ottawa, 1961)
Analog MOS integrated circuits, signal processing, analog and digital filters

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

Jack Willis, B.Sc. (U. London, 1945)
Active circuits, electronic systems

Associate Professors

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

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

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

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

* Also Professor Emeritus of Anesthesiology

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

Ingrid M. Verbaawhede, Ph.D. (Katholieke U., Leuven, Belgium, 1991)
Embedded systems, VLSI, architecture and circuit design methodologies for applications in security, wireless communications and signal processing

Richard D. Wesel, Ph.D. (Stanford, 1996)
Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and detection

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

Assistant Professors

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

Yuankun Ethan Wang, Ph.D. (Texas, Austin, 1999)
Smart antennas, RF and microwave power amplifiers, numerical techniques, DSP techniques for microwave systems, phased arrays, wireless and radar systems, microwave integrated circuits

Adjoint Professors

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

Elliott R. Brown, Ph.D. (Cal Tech, 1985)
Ultrafast electronics and optoelectronics, microwave and power electronics, infrared and RF sensors and materials, biomedical and remote chem-bio sensors

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

Brian H. Kolner, Ph.D. (Stanford, 1985)
Ultrafast light pulse generation and detection, compact femtosecond sources, mode-locking and pulse compression, noninvasive characterization of high-speed semiconductor devices and circuits

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

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

Adjunct Associate Professor

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

Adjunct Assistant Professor

Charles Chien, Ph.D. (UCLA, 1995)
End to end radio systems for high-speed adaptive wireless multimedia communications, multiband adaptive radio front-end architecture, adaptive spread-spectrum transceiver architectures, and
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.

2. Physics for Electrical Engineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 1. Introduction to modern physics necessary to understand solid-state devices, including elementary quantum theory, Fermi energies, and the concept of electrons in solids. Derivation of electrical properties of holes and junctions. Letter grading.


110. Circuit Analysis II. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 110 or Computer Science 15 or Digital and Analog Circuits for Low-power High-performance Chips. Experiments involving A/D and D/A converters, digital circuit analysis and design. Modern logic families (TTL, ECL, NMOS, CMOS), integrated circuit (IC) layout, MSI digital circuits (flip-flops, registers, counters, PLAs, etc.), computer-aided simulation of digital circuits. Letter grading.

115D. VLSI System Design. (4) Lecture, three hours; discussion, one hour; laboratory, four hours. Requisites: course 115B, 115C or 115D. Familiarity with digital circuit, logic design, and computer architecture assumed. VLSI design from a systems perspective, with focus on (1) core VLSI concepts such as datapath design, clocking, power, speed, area trade-off, input/output, packaging, etc. and (2) behavioral, register-transfer, logic, and physical-level structured VLSI design using CAD tools and hardware description languages such as VHDL. Letter grading.

Upper Division Courses

100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 1 or Physics 1C. Mathematics 33A, 33B. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transients, and traveling wave behavior, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.

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

115B. 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 thin-film hybrid techniques. Construction of amplifier using hybrid thick film techniques. Letter grading.

115C. Digital Electronics Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course 115B. Transistor-level digital circuit analysis and design. Modern logic families (TTL, ECL, NMOS, CMOS), integrated circuit (IC) layout, MSI digital circuits (flip-flops, registers, counters, counters, PLAs, etc.), computer-aided simulation of digital circuits. Letter grading.
116D. Digital Design Project Laboratory. (4) (Same as Computer Science M152B.) Laboratory, four hours; discussion, two hours; outside study, six hours. Requisite: course 116C 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. Mangione-Smith (F, W, Sp)

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

Mr. Srivastava (F, W, Sp)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to principles of operation of CMOS transistors and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Letter grading.

Mr. K.L. Wang, Mr. Woo (W, Sp)

122AL. Semiconductor Devices Laboratory. (5) Lecture, four hours; laboratory, four hours; outside study, seven hours. Requisites: courses 2, 121B (may be taken concurrently). Design fabrication and characterization of p-n junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Letter grading.

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

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 2 or Physics 1C. Limit ed to junior/senior engineering majors. Fundamentals of solid-state, introduction to quantum mechanics and quantum statistics applied to solid-state, Crystal structure, energy levels in solids, and band theory and semiconductor properties. Letter grading.

Mr. Fetterman, Mr. Yablonovitch (F)

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

Mr. Brown, Mr. Stafsudd (W)

124. Semiconductor Physical Electronics. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 123A. Band structure of semiconductors, experimental probes of basic band structure parameters, statistics of carriers, carrier transport properties at low fields, excess carrier transport properties, carrier recombination mechanisms, heterojunction properties. Letter grading.

Mr. Brown, Mr. Pan (W)

129D. Semiconductor Processing and Device Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisite: course 121B. Introduction to CAD tools used in integrated circuit processing and device design. Device structure optimization is based on PISCES; process integration tool is based on SUPREM. Course familiarizes students with the tools. Using CAD tools, a CMOS process integration to be designed. Letter grading.

Mr. Woo (Sp)

131A. Probability. (4) Lecture, four hours; discussion, one hour; outside study, 10 hours. Requisites: course 102, Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables and their distributions and densities, moments, characteristic functions, and limit theorems. Applications to communication, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading.

Mr. Roychowdhury (F, W)

131B. Introduction to Stochastic Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Introduction to concepts of stochastic processes, emphasizing continuous and discrete-time stationary processes, correlation function and spectral density, linear transformation, and mean-square estimation. Applications to communication, control, and signal processing. Introduction to computer simulation and analysis of stochastic processes. Letter grading.

Mr. Balakrishnan, Mr. Yao (Sp)


Mr. Rubin (W)


Mr. Jacobson, Mr. Vandenbergh (W)


Mr. Levan, Mr. P.K.C. Wang (F, Sp)

142. Linear Systems: State-Space Approach. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102. State-space methods of linear system analysis and synthesis, with application to problems in networks, control, and system modeling. Letter grading.

Mr. Levan, Mr. P.K.C. Wang (Sp)

M150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Biomedical Engineering M150L and Mechanical and Aerospace Engineering M180L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisite: course 121B. Introduction to micromachining and MEMS technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Letter grading.

Mr. Judy (F)

Mr. Vos (F, Sp, alternate years)

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

Mr. Rahmat-Samii (F, Sp)

162A. Wireless Communication Links and Antennas. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 161. Basic properties of transmitting and receiving antennas and antenna arrays. Array synthesis. Adaptive arrays. Friis transmission formula, radar equations. History and current technology in wireless communications (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage and capacity, interference and multipath fading, ray bending, and other propagation phenomena. Letter grading.

Mr. Rahmat-Samii (Sp)

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

Mr. Itoh (W)

163B. Microwave and Millimeter Wave Active Devices. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 121B. MESFET, HEMT, HBT, IMPATT, Gunn, small signal models, noise model, large signal model, loadpull method, parameter extraction technique. Letter grading.

Mr. Chang, Mr. Pan (Sp)

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

Mr. Itoh (F)

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

Mr. Itoh, Mr. Jialal (W)
210B. Optimal Linear Estimation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 113, 131B, 210A. Mathematics 115A. Unified treatment of fundamental concepts and basic topics in adaptive filtering, Wiener filtering, Kalman filtering, and H_0 filtering. Emphasis on geometric, equivalence, and duality arguments. Development of array methods. Discussion of practical issues. Examples of applications from fields of signal processing, communications, biomedical engineering, finance, and control. Letter grading. Mr. Sayed (Sp)

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

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


212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems; polyphase representation; multistage implementations; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; paraunitary filter banks; wavelet transform and its relation to multirate filter banks. Letter grading. Mr. Wilson (W)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 212A, M216A. Digital filter design concepts for analog, digital, and mixed-signal signal processing circuits; integrated circuit modules for digital signal processing; programmable signal processors; CAD tools and cell libraries for application-specific integrated circuit design; case studies of speech and image processing circuits. Letter grading. Mr. Jain (Sp)

214A. Digital Speech Processing. (4) (Same as Biomedical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 113. Theory and applications of digital processing of speech signals. Mathematical models of human speech production and perception mechanisms, speech analysis/synthesis. Techniques include linear prediction, filter-bank models, and homomorphic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Lecture, laboratory. Ms. Alwan (Sp)

214B. Advanced Topics in Speech Processing. (4) Lecture, three hours; computer assignments, two hours; outside study, seven hours. Requisite: course M214A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and machine. Physiology and psychoacoustics of human perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired. Letter grading. Ms. Alwan (Sp, even years)

215A. Analog Integrated Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115B. Analysis and design of analog integrated circuits. MOSFET and bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and discriminators, bandgap references. Letter grading. Mr. Razavi (F)

215B. Advanced Digital Integrated Circuits. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 115C, M216A. Analysis and comparison of modern logic families (CMOS, bipolar, BiCMOS, GaAs). MSI digital circuits (flipflops, registers, counters, PLAs). VLSI memories (ROM, RAM, CCD, bubble memories, EPROM, EEPROM) and VLSI systems. Letter grading. Ms. Alsaabuwhehed (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)

215D. Analog Microsystem Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 215A. Analysis and design of data conversion integrators, converters, and architectures. D/A conversion techniques, A/D converter architectures, building blocks, precision techniques, discrete- and continuous-time filters. Letter grading. Mr. Abidi (Sp)

215E. Signaling and Synchronization. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 215A, M216A. Analysis and design of circuits for synchronization and communication for VLSI systems. Use of both digital and analog design techniques to improve data rate of electronics between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading. Mr. C.K. Yang (Sp)

216A. Design of VLSI Circuits and Systems. (4) (Same as Computer Science M258A.) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisites: courses M16 or Computer Science M16A, and 115A. Recommended: course 215E. Design of VLSI circuits and systems. Topics include digital logic design, advanced VLSI design techniques, and design methodology for complex integrated circuits. Letter grading. Mr. C.K. Yang (F)

216B-216C. LSI in Computer System Design. (4-4) (Same as Computer Science M258B-M258C.) Lecture, four hours; laboratory, four hours. Requisite: course 216A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. In Progress (M216B) and Letter (M216C) grading. Mr. Jain, Mr. Mangione-Smith

217. Biomedical Imaging. (4) (Same as Biomedical Engineering M217.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 114D or 211A. Mathematical principles of medical imaging modalities: X-ray, computed tomography, magnetic resonance imaging, ultrasound, positron emission tomography, single photon emission computed tomography, magnetic resonance imaging. Topics include basic principles of each imaging system, image reconstruction algorithms, systems configurations and their effects on reconstruction algorithms, specialized imaging techniques for specific applications such as flow imaging. Letter grading. Ms. Liporace (Sp)

219. Topics in Circuits and Signal Processing. (4) Lecture, three hours; outside study, nine hours. Requisite: course 215A. Analysis of circuit topics selected from research areas in circuit theory, integrated circuits, or signal processing. Letter grading. Mr. Villasenor, Mr. Yang

221A. Physics of Semiconductor Devices I. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of junction devices and diode circuits. Letter grading. Mr. Woo (F)

221B. Physics of Semiconductor Devices II. (4) Lecture, four hours; outside study, eight hours. Prerequisites and design considerations of field effect devices and charge-coupled devices. Letter grading. Mr. C.K. Yang (F)

221C. Microwave Semiconductor Devices. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of microwave solid-state devices: Schottky barrier mixer diodes, IMPATT diodes, transferred electron devices, tunnel diodes, microwave transistors. Letter grading. Mr. Fetterman, Mr. Pan (W)

222. Integrated Circuits Fabrication Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Principles of integrated circuit fabrication processes. Technological limitations of integrated circuits design. Topics include bulk crystal and epitaxial growth, thermal oxidation, diffusion, ion implantation, chemical vapor deposition, dry etching, lithography, and metallization. Introduction of advanced process simulation tools. Letter grading. Mr. C.K. Yang (F, alternate years)

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

224. Solid-State Electronics II. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Techniques to solve Boltzmann transport equation, various scattering mechanisms in semiconductors, high field transport properties in semiconductors, Monte Carlo method in transport. Optical properties. Letter grading. Ms. Yarsham, Mr. Pan, Mr. Staffsudd (Sp, alternate years)

225. Physics of Semiconductor Nanostructures and Devices. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods for 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 topics in research areas, such as radiation effects in semiconductor devices, diffusion in semiconductors, optical and microwave semiconductor devices, nonlinear optics, and laser emission. Letter grading. Mr. Pan, Mr. Staffsudd (Sp, alternate years)

229S. Advanced Electrical Engineering Seminar. (2) Seminar, two hours; outside study, six hours. Preparation: successful completion of Ph.D. major field examination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on a tutorial topic and on a research topic in their dissertation area. May be repeated for credit. S/U grading. F,W,Sp

230A. Estimation and Detection in Communication and Radar Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Techniques of estimation and detection concepts in communication and radar engineering; random signal and noise characterizations by analytical and simulation methods; maximum-likelihood (ML) estimation and detection 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. Required: courses 132A, 230A. Basic concepts of digital communication systems; representation of bandpass waveforms; signal space analysis and optimum receivers in Gaussian noise; comparison of digital modulation methods; synchronization and adaptive equalization; application to modern communication systems. Letter grading. Mr. Fitz (W)


230D. Signal Processing in Communications. (4) Lecture, four hours; outside study, eight hours. Required: course 230C. Basic digital signal processing techniques for estimation and detection of signals in communication and radar systems. Optimization of dynamic range, quantization, and state constraints; DFT, convolution, FFT, NT, Winograd DFT, systolic array; spectral analysis-windowing, AR, and ARMA; system applications. Letter grading. Mr. Yao (Sp)

231A. Information Theory: Channel and Source Coding. Lecture, four hours; discussion, one hour; outside study, seven hours. Required: course 131A. Fundamentals on compression and transmission of information. Topics include limits and algorithms for lossless data compression, channel capacity, rate versus distortion in lossy compression, and information theory for multiple users. Letter grading. Mr. Potte, Mr. Wesel (F)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Required: 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. Required: 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. Required: course 232A. Queue modeling and analysis with applications to space-time digital switching systems and to integrated-service telecommunication systems. Fundamentals of traffic engineering and queueing theory. Queue size, waiting time, busy period, blocking, and stochastic process analysis for Markovian and non-Markovian models. Letter grading. Mr. Rubin (W)

232C. Telecommunication Architecture and Networks. (4) Lecture, four hours; outside study, eight hours. Required: course 232B. Analysis and design of integrated-service telecommunication networks and multiple-access procedures. Stochastic analysis of priority-based queueing system models. Queueing networks; network protocol architectures; error control; routing, flow, and access control. Applications to local-area, packet-radio, satellite, and computer communication networks. Letter grading. Mr. Rubin (Sp)

232D. Telecommunication Networks and Multiple-Access Communications. (4) Lecture, four hours; outside study, eight hours. Required: course 232B. Performance analysis and design of telecommunication networks and multiple-access communication systems. Topics include architectures, multiplexing and multiple-access, message delays, error/flow control, switching, routing, protocols. Applications to local-area, packet-radio, local-distribution, computer and satellite communication networks. Letter grading. Mr. Rubin (Sp)

232E. Graphs and Network Flows. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Required: course 136. Solution to analysis and synthesis problems which may be formulated as flow problems in capaci- ty constrained (or cost constrained) networks. Develop- ment of tools of network flow theory using graph theoretic methods; application to communication, transportation, and transmission problems. Letter grading. Mr. Roychowdhury, Mr. Rubin (W,Sp)

233A. Wireless Communication Theory. (4) Lecture, four hours; outside study, eight hours. Required: course 230B. Discussion of theory of physical layer and medium access design for wireless communica- tions. Topics include wireless signal propagation and channel modeling; interference and capacity limits of wireless models, performance analysis, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access techniques. Letter grading. Mr. Fitz

233B. Wireless Communication Systems. (4) Lecture, four hours; outside study, eight hours. Required: course 230B. Various aspects of physical layer and medium access design for wireless communication systems. Topics include wireless signal propa- gation and channel modeling, single carrier and spread spectrum modulation for wireless systems, diversity techniques, multiple-access techniques. Letter grading. Mr. Shenoy (Sp)

236A. Linear Programming. (4) Lecture, four hours; outside study, eight hours. Required: Mathematics 115A or equivalent knowledge of linear algebra. Basic graduate course in linear optimization. Geometry of linear programming. Duality, Simplex method. Inte- rior-point methods. Decomposition and large-scale linear programming. Quadratic programming and complementary pivot theory. Engineering applica- tions. Introduction to integer linear programming and computational complexity theory. Letter grading. Mr. Jacobsen, Mr. Vandenberghe (F)


M237. Dynamic Programming. (4) Formerly numbered 237.) (Same as Mechanical and Aerospace Engineering M276.) Lecture, four hours; outside study, eight hours. Required: course 232A or 236A or 236B. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, opti- mal control and estimation, Markov decision processes, combinatorial optimization, communications. Let- ter grading. Mr. Jacobsen, Mr. Vandenberghe (Sp)

239AS. Topics in Communication. (4) Lecture, four hours; outside study, eight hours. Topics in one or more special aspects of communication systems, such as phase-coherent communication systems, optical fiber, and time-varying channel. Subject may be repeated for credit with topic change. Letter grading.

239BS. Topics in Operations Research. (4) Lecture, four hours; outside study, eight hours. Treatment of one or more selected topics from areas such as integer programming; combinatorial optimization; net- work synthesis; scheduling, routing, location, and de- sign; and design of modern communication networks and multiple-access communication systems. Mathematical programming algorithms; stochastic programming; applications in engineering, computer science, economics. May be repeated for credit with topic change. Letter grading.

M240A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Mechanical and Aerospace Engineering M270A.) Lecture, four hours; outside study, eight hours. Required: course 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenval- ues and eigenvectors, singular values, Cayley-Hamil- ton theorem, Jordan form; solution of state equa- tions: stability, controllability, observability, reachability, and minimality. Interaction between state feedback and observers; separation principle. Connections with transfer function techniques. Letter grading. Mr. Pagani (F)

240B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Required: courses 141, M240A. Introduction to optimal control, with emphasis on detailed study of LQR, or linear regulators with quadratic cost criteria. Relationships to classical control system design. Letter grading. Mr. Levian (W)

M240C. Optimal Control. (4) (Same as Chemical Engineering M280C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Required: course 240B. Applications of variational methods, Pontryagin maximum principle, Hamilton/Jacobi/Bellman equation (dynam- ic programming) to optimal control of dynamic sys- tems modeled by nonlinear ordinary differential equa- tions. Letter grading. Mr. P.K.C. Wang (Sp)


241C. Stochastic Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 240B, 241B. Linear quadratic Gaussian theory of optimal feedback control of stochastic systems; discrete-time state-space models; sigma algebra equivalence and separation principle; dynamic programming; compensator design for time invariant systems; feedback control and servomechanisms, extensions to nonlinear systems; applications to interception guidance, gust alleviation. Letter grading. Mr. Balakrishnan (Sp)

M242A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Mechanical and Aerospace Engineering M272A.) Lecture, four hours; outside study, six hours. Requisites: M240A or Chemical Engineering M280A or Mecha
nical and Aerospace Engineering M270A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Liapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading. Mr. K.C. Wang (Sp)

243. Robust and Optimal Control by Convex Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: course M240A. Multivariable robust control, including H2 and H-infinity optimal control and the application of convex analysis and synthesis against structured uncertainty. Emphasis on convex methods for analysis and design, in particular linear matrix inequality (LMI) approach to control. Letter grading. Mr. Pagador (Sp)

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

249S. Topics in Control. (4) Seminar, four hours; outside study, eight hours. Thorough treatment of one or more aspects of control theory and applications, such as computational methods for optimal control; stability of distributed systems; identification; adaptive control; nonlinear filtering; differential games; applications to flight control, nuclear reactors, process control, biomedical problems. May be repeated for credit with topic change. Letter grading.

M250A. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Biomedical Engineering M250A and Mechanical and Aerospace Engineering M280L) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M150L. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. Judy (W)

M250B. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Biomedical Engineering M250B and Mechanical and Aerospace Engineering M280L) Lecture, three hours; discussion, one hour; outside study, eight hours. Preparatory modern physics (or course 123A), linear algebra, and ordinary differential equations courses. Principles of quantum mechanics for applications in lasers, solid-state physics, and nonlinear optics. Topics include eigenfunction expansions, observables, Schrödinger equation, uncertainty principle, central force problems, Hilbert spaces, WKB approximation, matrix mechanics, density matrix formalism, and radiation theory. Letter grading. Mr. M. Itoh (Sp)

271. Classical Laser Theory. (4) Lecture, four hours; outside study, eight hours. Preparation: modern physics (or course 123A). Laser fabrication, single-mode and multimode lasers, laser diodes, and laser amplifiers. Letter grading. Mr. Joshi (W)


273. Nonlinear Optics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 172D, 270B. Nonlinear optical susceptibility and modulation, crystal optics, electro-optics, and magneto-optics. Sum- and difference-frequency generation. Harmonic and parametric generation. Stimulated Raman and Brillouin scattering. Four-wave mixing and phase conjugation. Field-induced index changes and self-phase modulation. Letter grading. Mr. Liu, Mr. Yablonovitch (W, alternate years)

274. Fiber Optic System Design. (4) Lecture, three hours; outside study, nine hours. Requisites: courses 173DL and/or 174. Top-down introduction to physical layer design in fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and computer-controlled optical systems. Letter grading. Mr. Joshi (Sp)

275. Special Topics in Quantum Electronics. (4) Lecture, four hours; outside study, eight hours. Current research topics in quantum electronics, lasers, nonlinear optics, optoelectronics, ultrafast phenomena, fiber optics, and lightwave technology. May be repeated for credit. Letter grading. Mr. Joshi, Mr. Wu (F,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. Letter grading. Mr. Joshi, Mr. Mori (W) 285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M185, and 285A or Physics 222A. Interaction of intense electromagnetic waves with plasmas: waves in inhomogeneous and bounded plasmas, nonlinear wave coupling and damping, parametric instabilities, anomalous resistivity, shock waves, echoes, laser heating. Emphasis on experimental considerations and techniques. Letter grading. Mr. Chen, Mr. Joshi (Sp)


286. Seminar: Research Topics in Electrical Engineering. (2) Seminar, two hours; outside study, four hours. Advanced study and analysis of current topics in linear optical communications. Current research and literature in research specialty of faculty member teaching course. May be repeated for credit. S/U grading.
Materials Science and Engineering

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Mark S. Goosney, Ph.D., Chair
Jenn-Ming Yang, Ph.D., Vice Chair
Ya-Hong Xie, Ph.D., Vice Chair

Professors
Alan J. Ardell, Ph.D.
Russel E. Caflisch, Ph.D.
Emily C. Carter, Ph.D.
Bruce S. Dunn, Ph.D., NSG Chair (Nippon Sheet Glass Company Professor of Materials Science)
Vidvuds Ozolins, Ph.D.
Christian N.J. Wagner, Dr.rer.nat.
George H. Sines, Ph.D.
Aly H. Shabaik, Ph.D.

Assistant Professors
Vidvuds Ozolins, Ph.D.
Benjamin Wu, D.D.S., Ph.D.

Adjunct Professors
Eric P. Bescher, Ph.D.
Harry Patton Gillis, Ph.D.
John J. Gilman, Ph.D.
Marek A. Przystupa, Ph.D.

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

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

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

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

A joint major field, Chemistry/Materials Science, is offered to students enrolled in the Department of Chemistry and Biochemistry (College of Letters and Science). The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

Undergraduate Program Objectives
The Materials Engineering major at UCLA prepares undergraduate students for employment or advanced studies with industry, the national laboratories, state and federal agencies, and academia. To meet the needs of these constituencies, the objectives of the undergraduate program are to produce graduates who (1) possess a solid foundation in materials science and engineering, with emphasis on the fundamental scientific and engineering principles that govern the microstructure, properties, processing, and performance of all classes of engineering materials, (2) understand materials processes and the application of general natural science and engineering principles to the analysis and design of materials systems of current and/or future importance to society, (3) have strong skills in independent learning, analysis, and problem solving, with special emphasis on design of
engineering materials and processes, communication, and an ability to work in teams, and (4) understand and are aware of the broad issues relevant to materials, including professional and ethical responsibilities, impact of materials engineering on society and environment, contemporary issues, and need for lifelong learning.

Materials Engineering B.S.
The ABET-accredited materials engineering program is designed for students who wish to pursue a professional career in the materials field and desire a broad understanding of the relationship between microstructure and properties of materials. Metals, ceramics, and polymers, as well as the design, fabrication, and testing of metallic and other materials such as oxides, glasses, and fiber-reinforced composites, are included in the course contents.

The Major
Course requirements are as follows (182 or 183 minimum units required):
1. Five core courses: Chemical Engineering M105A (or Mechanical and Aerospace Engineering M105A), Civil and Environmental Engineering 108, Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102
3. Three elective courses from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical Engineering 2, 123A, 123B, 124, Materials Science and Engineering 111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C
4. One course from Electrical Engineering 131A or Mathematics 170A or Statistics 100A, plus 8 additional units from Chemistry and Biochemistry 30A, 30AL, Materials Science and Engineering 170, 171, or by petition, upper division courses from engineering, intermediate or advanced foreign language, mathematics, or physical or life sciences. Intermediate foreign language courses may be lower division
6. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

Electronic Materials Option
Course requirements are as follows (195 or 196 minimum units required):
2. Materials Science and Engineering 10, 110, 110L, 120 (or Electrical Engineering 2), 121, 122, 130, 131, 131L, 140; Electrical Engineering 121B, 122AL, 123A, 123B, and two courses from Materials Science and Engineering 132, 150, 160; Mechanical and Aerospace Engineering 181A or 182A
3. Four elective courses from Materials Science and Engineering 111, 143A, 143B, 150, 160; Electrical Engineering 110, 124, 131A, 172; 4 laboratory units from Materials Science and Engineering 90L
5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

Graduate Study
For information on graduate admission, see Graduate Programs, page 23.
The following introductory information is based on the 2004-05 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.

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.
Materials Science and Engineering M.S.

Areas of Study
There are three main areas in the M.S. program: ceramics and ceramic processing, electronic and optical materials, and structural materials. Students may specialize in any one of the three areas, although most students are more interested in a broader education and select a variety of courses. Basically, students select courses which serve their interests best in regard to thesis research and job prospects.

Course Requirements
Thesis Plan. Nine courses are required, of which six must be graduate courses. The courses are to be selected from the following lists, although suitable substitutions can be made from other engineering disciplines or from chemistry and physics with the approval of the departmental graduate adviser. Two of the six graduate courses may be Materials Science and Engineering 598 (thesis research). The remaining three courses in the total course requirement may be upper division courses.

Comprehensive Examination Plan. Nine courses are required, six of which must be graduate courses, selected from the following lists with the same provisions listed under the thesis plan. Three of the nine courses may be upper division courses.

Electronic and optical materials: Materials Science and Engineering 111, 121, 122, 143A, 151, 161, 162, 200, 201, 244, 246A, 246D, 298.

Structural materials: Materials Science and Engineering 111, 121, 122, 143A, 151, 161, 162, 200, 201, 221, 222, 223, 244, 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.

Written and Oral Qualifying Examinations
During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination which encompasses the body of knowledge in materials science. After all coursework is completed in the major and minor fields, students take a written preliminary examination in the major field. Students may not take an examination more than twice. After passing both preliminary examinations, students take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student's preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines
Ceramics and ceramic processing, electronic and optical materials, and structural materials.

Course Requirements
There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed for the written and oral preliminary examinations.

The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of knowledge contained in nine courses, at least six of which must be graduate courses, plus the current literature in the area of specialization. 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. Grades of B— or better with a grade-point average of at least 3.33 in all courses included in the minor field, are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor field is selected to support the major field and is usually a subset of the major field.

For information on completing the Engineer degree, see Schoolwide Programs, Courses, and Faculty.

Fields of Study

Ceramics and Ceramic Processing
The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials
The electronic and optical materials field provides an area of study in the science and technology of electronic materials which includes semiconductors, optical

cereamics, and thin films (metal, dielectric, and multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications which include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

**Structural Materials**

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

**Facilities**

Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Nondestructive Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Glass and Ceramics Research Laboratories
- X-Ray Diffraction Laboratory
- Thin Film Deposition Laboratory
- Mechanical Testing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Electron Microscopy Laboratories with a scanning transmission electron microscope (100 keV), a field emission transmission electron microscope (200 keV), and a scanning electron microscope, all equipped with a full quantitative analyzer, a stereo microscope, micro-camera, and metallurgical microscopes.

**Faculty Areas of Thesis Guidance**

**Professors**

Alan J. Ardell, Ph.D. (Stanford, 1964)
Irradiation-induced precipitation, high-temperature deformation of solids, electron microscopy, physical metallurgy of aluminum/lithium alloys, precipitation hardening

Theory and numerical simulation for materials physics, epitaxial growth, nanoscale systems, semiconductor device properties and design in applications to quantum well devices, quantum dots, nanocrystals and quantum computing

Emily A. Carter, Ph.D. (Cal Tech, 1987)
Development and application of first principles, quantum mechanical and multi-scale models of materials

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

Naor M. Goniem, Ph.D. (Wisconsin, 1977)
Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relaxation in epitaxial semiconductors and device structures, high-resolution X-ray diffraction of semiconductors, ceramics, and high-strength alloys

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

H. Thomas Hahn, Ph.D. (Pennsylvania State, 1971)
Nanocomposites, multifunctional composites, nanomechanics, rapid prototyping, information systems

Richard B. Kaner, Ph.D. (Pennsylvania, 1984)
Rapid synthesis of high-temperature materials, conducting polymers as separation membranes for enantiomers, synthesis of carbon nanoscrolls and composites

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

Qibing Pei, Ph.D. (Chinese Academy of Sciences, 1990)
Electroactive polymers through molecular design and nano-engineering for electronic devices and artificial muscles

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

Ya-Hong Xie, Ph.D. (UCLA, 1986)
Hetero-epitaxial growth of semiconductor thin films: strained Si, self-assembled quantum dots, and other epitaxial nano-structures; nano-patternning using diblock copolymer; Si substrate impedance engineering for mixed-signal integrated circuit technologies

Jenn-Ming Yang, Ph.D. (Delaware, 1986)
Mechanical behavior of polymer, metal, and ceramic matrix composites, electronics packaging

Yang Yang, Ph.D. (Massachusetts-Lowell, 1992)
Conjugated polymers and applications in optoelectronic devices such as light-emitting diodes, photodiodes, and field-effect transistors

**Professors Emeriti**

David L. Douglass, Ph.D. (Ohio State, 1958)
Oxidation and sulfidation kinetics and mechanisms, materials compatibility, defect structures, diffusion

William Klement, Jr., Ph.D. (Cal Tech, 1962)
Phase transformations in solids, high-pressure effects on solids

Glass science, ceramics, electrical properties of amorphous materials, materials recycling

Aly H. Shabaik, Ph.D. (UC Berkeley, 1966)
Metal forming, metal cutting, mechanical properties, friction and wear, biomaterials, manufacturing processes

Geoff H. Sines, Ph.D. (UCLA, 1953)
Fracture of ceramics, fatigue of metals, carbon-carbon composites, failure analysis

Christian N.J. Wagner, Dr rer nat. (U. des Saarlandes, 1967)
X-ray and neutron diffraction; structure of liquid and amorphous alloys, and plastically deformed metals; biomaterials; thin films; residual stresses

Alfred S. Yue, Ph.D. (Purdue, 1957)
Semiconductor eutectics; electronic materials for solar cell and detector applications, solidification and crystal growth

**Assistant Professors**

Vidvuds Ozolins, Ph.D. (Kungliga Tekniska H gskolan, Stockholm, 1998)
Theory of materials, first-principles modeling of phase transformations in bulk and surface systems, vibrational and electronic properties

Benjamin Wu, Ph.D. (MIT, 1997)
Processing, characterization, and controlled delivery of biological molecules of bioerodible polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

**Adjunct Professors**

Eric P. Bescher, Ph.D. (UCLA, 1987)
Advanced cementitious materials, sol-gel materials, organic/inorganic hybrids

Harry Patton Gilliss, Ph.D. (U. Chicago, 1974)
Application of surface science and chemical dynamics techniques to elucidate fundamental molecular mechanisms and optimize practical processes

John J. Gilmartin, Ph.D. (Columbia U., 1952)
Mechanochemistry, dislocation mobility, metallic glasses, fracture phenomena, shock and deterioration fronts, research management theory

Marek A. Przystupa, Ph.D. (Michigan Tech, 1988)
Mechanical behavior of solids
Lower Division Courses

10. Freshman Seminar: New Materials. (2) Formerly numbered 88.) Seminar, two hours; outside study, four hours. Preparation: high school chemistry and physics. Not open to students with credit for course 14. Introduction to basic concepts of materials science and new materials vital to advanced technology. Microstructural analysis and various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. Letter grading. Mr. Ono (F)

14. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, 20L, Physics 1A, 1B. General introduction to different types of materials used in engineering designs: metals, ceramics, plastics, and composites, relationship between structure (crystals and microstructure) and properties of technological materials. Illustration of their fundamental differences and their applications in engineering. Letter grading. Mr. Dunn (W)

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.

90L. Physical Measurement in Materials Engineering. (2) Laboratory, four hours; outside study, two hours. Various physical measurement methods used in materials science and engineering. Mechanical, thermal, electrical, magnetic, and optical techniques. Letter grading. Mr. Ono (Sp)

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

Upper Division Courses


110L. Introduction to Materials Characterization A Laboratory. (2) Lecture, two hours; outside study, four hours. Requisite: course 14. Experimental techniques and analysis of materials through X-ray scattering techniques; powder method, Laue method, crystal structure determination, and special projects. Letter grading. Mr. Goorsky (F)

111. Introduction to Materials Characterization B (Electron Microscopy). (4) Lecture, three hours; laboratory, two hours. Requisites: courses 14, 110. Characterization of microstructure and morphology of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Letter grading. Mr. Ardel (W)

120. Physics of Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 14, 110 (or Chemistry 113A). Introduction to electrical, optical, and magnetic properties of metals; electrical conduction and band structure; Bloch wave; behavior of magnetic materials; introduction to band theory and Schrödinger wave equation. Crystal bonding and lattice vibrations. Mechanics and characterization of deformations; mechanical, optical, magnetic, and dielectric properties. Letter grading. Mr. Dunn (W)

121. Materials Science of Semiconductors. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and ion-beam techniques. Heterostructures, band-gap engineering, development of new materials for optoelectronic applications. Letter grading. Mr. Dunn (Sp)

121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes: discussion, 30 minutes; laboratory, two hours; outside study, three hours. Corequisite: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading. Mr. Tu (W)

122. Principles of Electronic Materials Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 14. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading. Mr. Goorsky (W)

123. Electronic Packaging and Interconnection. (2) Lecture, two hours; outside study, six hours. Various electronic packaging methods and interconnection technologies. Design, fabrication, and testing of complex microelectronic components, interconnections, and assemblies. Letter grading. Mr. Tu (W)

130. Phase Relations in Solids. (4) Lecture, four hours; outside study, eight hours. Requisites: course 14, and Chemical Engineering M105A or Mechanical and Aerospace Engineering M105A. Summary of thermodynamic laws, equilibrium criteria, solution thermodynamics, mass-transport laws, 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 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) Lecture, two hours; outside study, four hours. Corequisite: course 131. Design of heat-treating cycles and performing experiments to study interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. Mr. Tu (W)

132. Structure and Properties of Metallic Alloys. (4) Lecture, three hours; discussion, one hour; 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, 139. Introduction to the selection of metals and materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymeric, ceramic, and composite materials, coatings. Materials selection, treatment, and selection of materials as part of successful design. Letter grading. Mr. Przystupa (Sp)

141L. Computer Methods and Instrumentation in Materials Science. (2) Formerly numbered 191L.) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to junior/senior Materials Science and Engineering majors. Interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading.

Mr. Goorsky (W)

143A. Mechanical Behavior of Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 14. Recommended: Civil Engineering 108. Plastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocation, fracture, microstructural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. Wilson (W)

150. Introduction to Polymers. (4) Lecture, three hours; laboratory, two hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, stereochemistry of morphological and their effects on physical properties. Glassy polymers, springy polymers, elastomers, 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, 141L, 160. Introduction to the use of composites as a fundamental theme between structure and mechanical properties of composite materials. Fiber and particulate reinforcement. Properties of fiber, matrix, and interfaces. Selection of microstructures and material systems. Letter grading. Mr. Ono (Sp)

160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 14, 130. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for 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, functional, electronic, and optical properties. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting. Microstructure properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading. Mr. Dunn (W, even years)


162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 134, Electrical Engineering 100. Utilization of ceramics in microelectronics; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferroelectric ceramics and electro-optic devices; optical waveguide applications and designs. Letter grading. Mr. Dunn (W, odd years)
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.

223. Materials Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131. Fabrication, structure, and properties of thin films used in microelectronics for data and information processing. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading.

224. Deposition Technologies and Their Applications. (4) Lecture, four hours; outside study, nine hours. Designed for graduate engineering students. Deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-assisted vapor deposition processes, plasma spray, electrodeposition. Applications in semiconductor, chemical, optical, mechanical, and metallic industries. Letter grading.

Mr. Xie (Sp, even years)

CM180. Introduction to Biomaterials. (4) Same as Biomedical Engineering CM180L (Lecture, four hours; discussion, two hours; outside study, seven hours. Requisites: course 14, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and bio-compatibility. Concurrently scheduled with course CM280. Letter grading.

Mr. Wu (Sp)

188. Special Courses in Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in materials science and engineering for undergraduate students that are taught on experimental or temporary basis, such as courses taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor. 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. Occasionally, 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.

Graduate Courses


Mr. Dunn (F)


Mr. Ardel (Sp)

221. Science of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: 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)

246A. Mechanical Properties of Nonmetallic Crystalline Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Material and environmental factors affecting the properties of nonmetallic crystalline solids, including atomic bonding and structure, atomic-scale defects, microstructural features, residual stresses, temperature, stress state, strain rate, size, and surface conditions. Methods for evaluating mechanical properties. Letter grading.

Mr. Dunn (W, odd years)


Mr. Dunn (Sp, even years)


Mr. J.-M. Yang (W, even years)


Mr. Ono (W, odd years)

CM280. Introduction to Biomaterials. (4) Same as Biomedical Engineering CM280L (Lecture, four hours; discussion, two hours; outside study, eight hours. Requisites: course 110. Theory of diffraction of surfaces and near-surface layers of solid-state materials. Emphasis on scanning probe microscopy, Auger electron spectroscopy, X-ray photoelectron spectroscopy, X-ray fluorescence, electron spectroscopy, X-ray photoelectron spectroscopy, X-ray fluorescence, electron microscopy, Rutherford backscattering spectrometry. Applications in microelectronics, optoelectronics, metallurgy, polymers, biological and biocompatible materials, and catalysis. Letter grading.

Mr. Gillis, Mr. Goorsky (W)


Mr. Ono (W, even years)

243C. Dislocations and Strengthening Mechanisms in Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143A or Mechanical and Aerospace Engineering 156B. Elastic and plastic behavior of crystals, geometry, mechanics, and interaction of dislocations with different mechanisms of yielding, work hardening, and other strengthening. Letter grading.

Mr. Ardel (F, odd years)

244. Electron Microscopy. (4) Lecture, four hours; outside study, eight hours. Requisite: course 111. Essential features of electron microscopy, geometry of electron diffraction, kinematical and dynamical theories of electron diffraction, including anomalous absorption, applications of theory to defects in crystals. More advanced, direct lattice resolutions, Lorentz microscopy, laboratory applications of contrast theory. Letter grading.

Mr. Ardel (Sp, even years)


Mr. Goorsky (Sp, odd years)

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Mechanical and Aerospace Engineering

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Nasr M. Ghoumri, Ph.D., Vice Chair
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Professors
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Oddvar O. Bendiksen, Ph.D.
Gregory P. Carman, Ph.D.
Albert Carnesale, Ph.D., Chancellor
Ivan Catton, Ph.D.
Yong Chen, Ph.D.
Vijay K. Dhir, Ph.D., Dean
Rajit Gadh, Ph.D.
Nasr M. Ghoumri, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
H. Thomas Hahn, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
Chih-Ming Ho, Ph.D., Associate Vice Chancellor, Research (Ben Rich Lockheed Martin Professor of Aeronautics)
Ann R. Karagozian, Ph.D.
Chang-Jin (C-J) Kim, Ph.D.
J. John Kim, Ph.D. (Rockwell International Professor of Engineering)
Adrienne G. Lavine, Ph.D.
Kuo-Nan Liou, Ph.D.
Ajit K. Mal, Ph.D.
Anthony F. Mills, Ph.D.
Carlo D. Montemagno, Ph.D.
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Owen I. Smith, Ph.D.
Jason Speyer, Ph.D.
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Daniel C.H. Yang, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti
Andrew F. Charwat, Ph.D.
Perez P. Friedmann, Sc.D.
Walter C. Hurty, M.S.
Robert E. Kelly, Sc.D.
Cornelius T. Leondes, Ph.D.
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D. Lewis Mingori, Ph.D.
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Associate Professor
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Assistant Professors
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Emilio Frazzoli, Ph.D.
Yongho Sungtaek Ju, Ph.D.
H. Pirouz Kavehpour, Ph.D.
William S. Klug, Ph.D.
Laurent Pilone, Ph.D.

Senior Lecturer
Alexander Samson, Ph.D., Emeritus

Lecturers
Ravneesh A. 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.
Neil B. Morley, Ph.D.
Raymond Viskanta, Ph.D.
Xiang Zhang, Ph.D.

Scope
The Mechanical and Aerospace Engineering Department encompasses professional disciplines that are often divided into separate departments at other engineering schools. Curricula in aerospace engineering and mechanical engineering are offered on both the undergraduate and graduate levels. The Gourman Report ranked UCLAs mechanical engineering program tenth in the nation for undergraduate programs.

Because of the scope of the department, faculty research and teaching cover a wide range of technical disciplines. Research in thermal engineering emphasizes basic heat and mass transfer processes as well as thermal hydraulics. Topics in the area of design, dynamics, and control include robotics, mechanism design, control and guidance of aircraft and spacecraft, aero-mechanics, and dynamics and control of large space structures. Studies in structural mechanics range from fracture mechanics and wave propagation, structural dynamics and aerelasticity of helicopters and jet engine blades, computational transonic aerelasticity to structural optimization and synthesis, and mechanics of composite structures. In the area of fluid mechanics and acoustics, investigations are under way on combustion, flow instabilities, turbulence and thermal convection, aeroacoustics, and unsteady aerodynamics of turbomachines, helicopter rotors, and fixed-wing aircraft. Other areas of research include applied plasma physics, surface modification by plasma, fusion reactor design, experimental tokamak confinement physics, light water reactor safety; reliability and risk assessment methodology; and nuclear
materials. The department also has research activity in computer-aided design and manufacturing.

At the undergraduate level, the department offers accredited programs leading to B.S. degrees in Aerospace Engineering and in Mechanical Engineering. The former includes opportunity to emphasize propulsion, aerodynamics, design, dynamics and control, or structures and space technology, while the latter includes opportunity to emphasize design and manufacturing, dynamics and control, or fluids and thermal engineering.

At the graduate level, the department offers programs leading to M.S. and Ph.D. degrees in Mechanical Engineering and in Aerospace Engineering. An M.S. in Manufacturing Engineering is also offered.

Department Mission
The mission of the Mechanical and Aerospace Engineering Department is to educate the nation’s future leaders in the science and art of mechanical and aerospace engineering. Further, the department seeks to expand the frontiers of engineering science and to encourage technological innovation while fostering academic excellence and scholarly learning in a collegial environment.

Undergraduate Program Objectives
In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: (1) to teach students how to apply their rigorous undergraduate education to creatively solve technical problems facing society and (2) to prepare them for successful and productive careers or graduate studies in mechanical or aerospace or other engineering fields and/or further studies in other fields such as medicine, business, and law.

Aerospace Engineering B.S.
The ABET-accredited aerospace engineering program is concerned with the design and construction of various types of fixed-wing and rotary-wing (helicopters) aircraft used for air transportation and national defense. It is also concerned with the design and construction of spacecraft, the exploration and utilization of space, and related technological fields. Aerospace engineering is characterized by a very high level of technology. The aerospace engineer is likely to operate at the forefront of scientific discoveries, often stimulating these discoveries and providing the inspiration for the creation of new scientific concepts. Meeting these demands requires the imaginative use of many disciplines, including fluid mechanics and aerodynamics, structural mechanics, materials and aeroelasticity, dynamics, control and guidance, propulsion, and energy conversion.

The Major
Course requirements are as follows (191 minimum units required):

1. Ten department core courses: Civil and Environmental Engineering 108, Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 20, 102, 103, M105A, 105D, 157, 182A


3. Sixteen technical elective units (which should contain enough design units to satisfy the overall program requirement of at least 24 design units) selected from Mechanical and Aerospace Engineering 131A, 131AL, 132A, 133A, 133AL, 150C (heat and mass transfer, thermodynamics, combustion/propulsion); 153A (acoustics); 155, 163A, 169A (unless taken as part of the core), 171B, Civil and Environmental Engineering 137L, Electrical Engineering 142 (dynamics and control); Mechanical and Aerospace Engineering 156B, 166C, 168, 183 (structural and solid mechanics); Mechanical and Aerospace Engineering 150R, 161A (unless taken as part of the core), 161B, 161C, 161D (space technology); 162A, 162C (designs and mechanisms); Materials Science and Engineering 143A

4. Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

Mechanical Engineering B.S.
The ABET-accredited mechanical engineering program is designed to provide basic knowledge in thermodynamics, fluid mechanics, heat transfer, solid mechanics, mechanical design, dynamics, control, mechanical systems, manufacturing, and materials. The program includes fundamental subjects important to all mechanical engineers, with options in design and manufacturing, dynamics and control, and fluids and thermal engineering.

The Major
Course requirements are as follows (193 minimum units required):

1. Ten department core courses: Civil and Environmental Engineering 108, Electrical Engineering 100, Materials Science and Engineering 14, Mechanical and Aerospace Engineering 20, 102, 103, M105A, 105D, 157, 182A


3. Twenty technical elective units, to be selected from the three subject areas listed below, of which at least 12 units (including at least 4 laboratory units) should be from a single subject area:
Mechanical and Aerospace Engineering 131AL, 133AL, 157A

4. Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL

5. HSSEAS general education (GE) requirements; see Curricular Requirements on page 21 for details

6. Four free technical elective units selected from upper division courses offered by the department; students are strongly encouraged to consult their adviser

Graduate Study

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

The following introductory information is based on the 2004-05 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available from the Publications link at http://www.gdnet.ucla.edu. Students are subject to the degree requirements as published in Program Requirements for the year in which they matriculate.

The Department of Mechanical and Aerospace Engineering offers the Master of Science (M.S.) degree in Manufacturing Engineering, Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Aerospace Engineering, and Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Mechanical Engineering.

Aerospace Engineering M.S. and Mechanical Engineering M.S.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement.

The courses should be selected so that the breadth requirements and the requirements at the graduate level are met. The breadth requirements are only applicable to students who do not have a B.S. degree from an ABET-accredited aerospace or mechanical engineering program.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, M105A, 105D, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or 150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 250C, 250D, 250F, 253B, 254A, 255B, 256F, 263B, 269D, or 271B.

The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A or 156B, (5) 162B or 183.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 231A, 231B, 231C, 250A, 255A, M256A, M256B, M269A, or 271A.

The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, (3) take and pass three extra examination questions offered separately from each of the finals of three graduate courses, to be selected by the committee from a set of common department courses, or (4) take and pass an oral examination administered by the M.S. committee. In case of failure, students may be reexamined once with the consent of the graduate adviser.
Thesis Plan
The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Manufacturing Engineering M.S.

Areas of Study
Consult the department.

Course Requirements
Students may select either the thesis plan or comprehensive examination plan. At least nine courses are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Choices may be made from the following major areas:

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering M105A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, M171L, 199; Electrical Engineering 100, 101, 102, 103, 110L, M116D, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, M105A, 106D, 199.

Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 163A, 168, 174, 183, 184, 185.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, M280, 293, 294, 295, 296A, 296B, 297.

Additional Courses. The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design M226B, M227B, 227D; Computer Science 241A, 241B; Management 240A, 240D, 241A, 241B, 242A, 242B, 243A, 243B, 243C; Mathematics 120A, 120B.

Comprehensive Examination Plan
The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, (3) take and pass three extra examination questions offered separately from each of the finals of three graduate courses, to be selected by the committee from a set of common department courses, or (4) take and pass an oral examination administered by the M.S. committee. In case of failure, students may be reexamined once with the consent of the graduate adviser.

Aerospace Engineering Ph.D. and Mechanical Engineering Ph.D.

Major Fields or Subdisciplines
Dynamics; fluid mechanics; heat and mass transfer; manufacturing and design (mechanical engineering only); nanoelectromechanical/microelectromechanical systems (NEMS/MEMS); structural and solid mechanics; systems and control.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature and (2) the field represents an important research area for which there is no established major field in the department (condition 2 most often applies to recently evolving research areas or to areas for which there are too few faculty to maintain an established major field).

Students in an ad hoc major field must be sponsored by at least three faculty members, at least two of whom must be from the department.

Course Requirements
The basic program of study for the Ph.D. degree is built around major and minor fields. The established major fields are listed above, and a detailed syllabus describing each Ph.D. major field can be obtained from the Student Affairs Office. The program of study for the Ph.D. requires students to perform original research leading to a doctoral dissertation and to master a body of knowledge that encompasses material from their major field and breadth material from outside the major field. The body of knowledge should include (1) six major field courses, at least four of which must be graduate courses, (2) one minor field, (3) any three additional courses, at least two of which must be graduate courses, that enhance the study of the major or minor field.

The major field syllabus advises students as to which courses contain the required knowledge, and students usually prepare for the written qualifying examination (formerly referred to as the preliminary examination) by taking these courses. However, students can acquire such knowledge by taking similar courses at other universities or even by self-study.

The minor field embraces a body of knowledge equivalent to three courses, at least two of which must be graduate courses. Minor fields are often subsets of major fields, and minor field requirements are then described in the syllabus of the appropriate major field. Established minor fields with no corresponding major field can also be used, such as applied mathematics and applied plasma physics and fusion engineering. Also, an ad hoc field can be used in exceptional circumstances, such as when certain knowledge is desirable for a program of study that is not available in established minor fields.

Grades of B— or better with a grade-point average of at least 3.33 in all courses included in the minor field, and the three additional courses mentioned above are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only).
Written and Oral Qualifying Examinations
After mastering the body of knowledge defined in the major field, students take a written qualifying (preliminary) examination covering this knowledge. Students must have been formally admitted to the Ph.D. program or admitted subject to completion of the M.S. degree by the end of the quarter following the quarter in which the examination is given. The examination must be taken within the first two calendar years from the time of admission to the Ph.D. program. Students must be registered during the quarter in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student’s major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field.

After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years from the time of admission to the Ph.D. program. The nature and content of the examination are at the discretion of the doctoral committee but include a review of the dissertation prospectus and may include a broad inquiry into the student’s preparation for research.

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

Fields of Study
Dynamics
Features of the dynamics field include dynamics and control of physical systems, including spacecraft, aircraft, helicopters, industrial manipulators; analytical studies of control of large space structures; aeromechanical stability of helicopters; active control of helicopter vibrations; experimental studies of electromechanical systems; and robotics.

Fluid Mechanics
The fluid mechanics field includes theoretical, numerical, and experimental studies related to topics in fluid mechanics such as fluid instabilities, flow transition, numerical simulation of turbulence, flow control, computational aerodynamics, hypersonic flow, aerodynamic noise production, high-speed combustion, acoustically driven combustion 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, 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 micrometers and includes both experimental and theoretical studies covering fundamentals to applications. The study topics include microscience, top-down and bottom-up nano/micro fabrication technologies, molecular fluidic phenomena, nanoscale/microscale material processing, biomolecular signatures, heat transfer at the nanoscale, and system integration. The program is highly interdisciplinary in nature.

Structural and Solid Mechanics
The solid mechanics field features theoretical, numerical, and experimental studies, including fracture mechanics and damage tolerance, micromechanics with emphasis on technical applications, wave propagation and nondestructive evaluation, mechanics of composite materials, mechanics of thin films and interfaces, and investigation into coupled 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 composites structures, and analysis of adaptive structures.

Systems and Control
The systems and control field deals with modeling, analysis, and control of dynamical systems. Applied mathematics is used to develop methods for stability analysis, design of optimal and robust control systems, filtering, and system identification. Courses and research programs include theoretical analysis of the performance of systems and algorithms; computational methods for simulation, optimization, control, filtering, and identification; and experimental studies involving system identification and hardware implementation of real-time control and filtering. The field covers a broad spectrum of applications areas, primarily emphasizing problems in mechanical and aerospace engineering.

Ad Hoc Major Fields
The ad hoc major fields program has sufficient flexibility that students can form academic major fields in their area of interest if the proposals are supported by several faculty members. Previous fields of study included acoustics, system risk and reliability, and engineering thermodynamics. Nuclear science and engineering, a former active major field, is available on an ad hoc basis only.

Facilities
The Mechanical and Aerospace Engineering Department has a number of experimental facilities at which both fundamental and applied research is being conducted. More information is at http://www.mae.ucla.edu.
1. The Micro-Manufacturing Laboratory is equipped with a fume hood, a clean air bench, an optical table, a DI water generator, dicing saw, plating setup with Dynatronix power supply. Wentworth probe stations, various microscopes such as Endo View and Hirox 3-D High-Scope System, full video imaging capability such as a Sony Digital Camera system, as well as L-Edit mask layout software. It is used for MEMS research and complements the HSSEAS Nanoelectronics Research Facility, the 8,500-square-foot class 100/1000 clean room where most micromachining steps are carried out.

2. The Multifunctional Composites Laboratory provides equipment necessary to develop multifunctional nanocomposites and explore their applications by integrating technologies involving composites, nanomaterials, information, functional materials, biomimetics, and concurrent engineering. Some of the equipment in the laboratory includes an autoclave, a filament winder, a resin transfer molding machine, a waterjet cutting machine, a stereo lithography machine, a laminated object manufacturing machine, a coordinate measuring machine, a field emission scanning electron microscope, a scanning probe microscope, an FTIR, a rheometer, a thermal analysis system, an RCL analyzer, a microdielectric analyzer, an X-ray radiography machine, and a variety of mechanical testing machines.

3. The Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. The AVSIL contains a hardware-in-the-loop (HIL) simulator designed and built at UCLA that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the Interstate Electronics Corporation GPS Satellite Constellation Simulator. The UCLA flight control software can be modified to accommodate satellite-system experiments using real-time software, GPS receivers, and inter-vehicle modem communication.

4. The Nanoscale Heat Transfer and Thermoelectrics Laboratory (Nano-HTTL) is equipped with a scanning probe microscope (atomic force, scanning tunneling, scanning thermal, and scanning laser), infrared microscope with 4, m resolution, gas and solid-state lasers (argon, T-Sapphire, and semiconductor lasers) and optical systems, vacuum systems for low- to high-temperature property measurement (4 K-800 K), a probe station, various thin-film thermal conductivity and Seebeck coefficient measurement systems, analytical equipment, various computers for data acquisition, and an HP workstation for computational work.

5. The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, magnetostrictive, shape memory alloys, and fiber optic sensors. The laboratory has manufacturing facilities to fabricate magnetostrictive composites and thin film shape memory alloys. Testing active material systems is performed on one of four servo-hydraulic load frames. All of the load frames are equipped with thermal chambers, solenoids, and electrical power supplies.

6. The 3 x 3-foot Subsonic Wind Tunnel is used for research on unsteady aerodynamics on oscillating airfoils and instruction.

7. The Heat Transfer Laboratories are used for experimental research on heat transfer and thermal hydraulics. The laboratories are equipped with several flow loops, high-current power supplies, high-frequency induction power supplies, holography and hot-wire anemometry setups, and state-of-the-art data acquisition systems.

8. The Fluid Mechanics Research Laboratory includes a full line of water tunnels equipped with various advanced transducers (MEMS-based sensors and actuators, particle image anemometer, laser Doppler anemometer, hot-wire anemometers) and data acquisition systems.

9. The Computational Fluid Dynamics Laboratory has several medium-size 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.

10. The Combustion Research Laboratory includes a resonant dump combustor for the study of hazardous waste incineration, mixing and combustion tunnels for study of emissions reduction in fuel injection systems, and several flat flame burners and flow reactors. There are also extensive optical diagnostic capabilities. For flight testing, facilities at NASA Dryden Flight Research Center are used.

11. The Fusion Technology Center includes a number of state-of-the-art experimental facilities for conducting research in fusion engineering. The center includes experimental facilities for (1) liquid metal magnetohydrodynamic fluid flow, (2) thick and thin liquid metal systems exposed to intense particle and heat flux loads, and (3) metallic and ceramic material thermomechanics.

12. The Materials Degradation Characterization Laboratory is used for the characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and for research on fracture mechanics and ultrasonic nondestructive evaluation.

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

14. The Thin Films, Interfaces, Composites, Characterization Laboratory consists of a Nd:YAG laser of 1 Joule capacity with three ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 Kip-capacity servohydraulic biaxial test frame, walk-in freezer, polishing and imaging equipment for microstructural characterization for measurement and control study of thin film interface strength, NDE using laser ultrasound, de-icing of structural surfaces, and characterization of composites under multiaxial stress state.

15. The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for the purpose of processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with
plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power D.C. supplies (400kw), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

**Faculty Areas of Thesis Guidance**

**Professors**

Mohamed A. Abdou, Ph.D. (Wisconsin, 1973)
- Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermoelectromechanics, thermal fluids; electronics, plasma-material interactions, blankets and high heat flux components; experiments, modeling and analysis

Nasr M. Ghoniem, Ph.D. (Wisconsin, 1977)
- Distributed systems, including flexible control and identification of dynamical systems, computer science, and computer hardware

Vijay K. Dhir, 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

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
- Molecular fluidic phenomena, nanoelectro-mechanical/nano-electromechanical systems, direct handling of macromolecules, bionano technologies, DNA-based micro sensors

Oddvar O. Bendiksen, Ph.D. (UCLA, 1980)
- Heat transfer and fluid mechanics, transport phenomena in porous media, nucleonics heat transfer and thermal hydraulics, natural and forced convection, thermal/hydraulic stability, turbulence

Jason Speyer, Ph.D. (Harvard, 1968)
- Robotics and mechanisms, CAD/CAM systems, computer-controlled machines

Jeff S. Shamma, Ph.D. (MIT, 1988)
- Stochastic and deterministic optimal control and estimation with application to aerospace systems, guidance, flight control, and flight dynamics

Carlo D. Montemagno, Ph.D. (Notre Dame, 1981)
- Mechanics of solids, fractures and failure, wave propagation, nondestructive evaluation, composite materials

- Mechanics of solids, fractures and failure, wave propagation, nondestructive evaluation, composite materials

Richard Stern, Ph.D. (UCLA, 1964)
- Structural mechanics, optimization, computer-aided design and manufacturing, numerical control of manufacturing systems

Lucien A. Schmit, Jr., M.S. (MIT, 1950)
- Fluid mechanics, internal acoustics and noise produced by turbulent jets

David Okrent, Ph.D. (Harvard, 1951)
- Structural mechanics, optimization, computer-aided design and manufacturing, numerical control of manufacturing systems

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 O. Brien, M.S. (UCLA, 1949)
- Fluid mechanics, internal acoustics and noise produced by turbulent jets

Richard Stern, Ph.D. (UCLA, 1964)
- Fluid mechanics, internal acoustics and noise produced by turbulent jets

**Professors Emeriti**

Andrew F. Charette, Ph.D. (U.C Berkeley, 1952)
- Experimental fluid mechanics, two-phase flow, ocean thermal energy conversion

Emilio Frazzoli, Ph.D. (MIT, 2001)
- Algorithmic, geometric and computational methods for control of autonomous and distributed autonomous systems; flight control, aerodynamics, robotics, hybrid systems

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

Wallace C. Hury, M.S. (UCLA, 1948)
- Mechanics of structures, including large structural systems, design and analysis of aerospace structures, stability of motion in self-excited systems

- Thermal convection, thermocapillary convection, stability of shear flows, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics

Cornelius T. Leondes, Ph.D. (Pennsylvania, 1964)
- Applied dynamic systems control

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

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

Peter A. Monkewitz, Ph.D. (E.T.H., Federal Institute of Technology, Zurich, 1977)
- Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip O. Brien, M.S. (UCLA, 1949)
- Fluid mechanics, internal acoustics and noise produced by turbulent jets

Industrial engineering, environmental design, thermal and luminous engineering systems

David Okrent, Ph.D. (Harvard, 1951)
- Fast reactors, reactor physics, nuclear reactor safety, nuclear fuel element behavior, risk-benefit studies, nuclear environmental safety, fusion reactor technology

Russell R. O Neill, Ph.D. (UCLA, 1956)
- Systems engineering, maritime transportation systems

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

Chauncey Starr, Ph.D. (Rensselaer Polytechnic Institute, 1935)
- Risk-benefit analysis of technical systems, national energy policy

Richard Stern, Ph.D. (UCLA, 1964)
- Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics

**Exemplary Projects**

**Industrial Experience**

**Academic Experience**

**Research Experience**

**Professional Experience**

**Community Experience**

**Leadership Experience**

**Service Experience**

**Volunteer Experience**

**Personal Experience**

**Miscellaneous Experience**
Lower Division Courses

10. Introduction to Mechanical and Aerospace Engineering. (2) Lecture, two hours. Overview of fluid mechanics, heat and mass transfer, manufacturing and design, microelectromechanical systems, structural and solid mechanics, systems dynamics and control. Careers in mechanical and aerospace engineering industry. P/NP grading.


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.

94. Introduction to Computer-Aided Design and Drafting. (4) Lecture, two hours; laboratory, four hours. Fundamentals of computer graphics and two- and three-dimensional modeling on computer-aided design and drafting systems. Students use one or more on-line computer systems to design and display various objects. Letter grading.

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


103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

105A. Introduction to Engineering Thermodynamics. (4) Same as Chemical Engineering M105A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 202L, 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 thermodynamics. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading.


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.


133A. Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, M105A, 105D. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, reactive and nonreactive fluid flow systems. Letter grading.

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.

134. Design and Operation of Thermal Hydraulic Power Systems. (4) Lecture, three hours; laboratory, three hours; outside study, six hours. Requisites: courses 133A, 133AL. Thermal hydraulic design, maintenance and operation of power systems, gas turbines, steam turbines, centrifugal refrigeration units, absorption refrigeration units, compressors, valves and piping systems, and instrumentation and control systems. Letter grading.

136. Thermal Hydraulic Design of Nuclear and Other Power Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: courses 134, 133AL. Thermal hydraulic design of nuclear and other power systems, power generation and heat removal, power cycle, thermal hydraulic component design, overall plant design, steady state and transient operation. Letter grading.
CM140. Introduction to Biomechanics. (4) Same as Biomedical Engineering CM140.) Lecture, four hours; outside study, eight hours. Requisites: courses 102 (or Civil Engineering CM16A). Introduction to biomechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power elements. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading.

Mr. Gupta, Mr. Kabo (W)


Mr. Eldredge, Ms. Karagozian (W)

150B. Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 150A. Advanced aspects of potential flow theory. Incompressible flow around thin airfoils (C150A) and compressible flow: normal shocks, Prandtl/Meyer expansion. Linearized subsonic and supersonic flow around thin airfoils and wings. Wave drag. Transonic flow. Letter grading.

Mr. Zhong (Sp)


Ms. Karagozian, Mr. Smith (W)

150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, M105A. Thermodynamic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Letter grading.

Ms. Karagozian, Mr. Smith (F)

150R. Rocket Propulsion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, M105A, 105D. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rocket engines, and solar-powered vehicles. Current issues in launch vehicle technologies. Letter grading. Ms. Karagozian, Mr. Smith (Sp)

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

Mr. Eldredge (Sp, alternate years)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; outside study, eight hours. Requisite: course 1545. Classical preliminary design of an aircraft, including weight estimation, performance and stability, and control consideration. Term assignment consists of preliminary design of a low-speed aircraft. Letter grading.

Mr. Bendiksen (W)


Mr. Bendiksen (Sp)

154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and control; some basic ingredients needed for design of an aircraft. Effects of airplane flexibility on stability derivatives. Letter grading.

Mr. Bendiksen (F)

155. Intermediate Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrange equation, variational principles; central force motion; kinematics and dynamics of a rigid body. Euler equations, motion of rotating bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading. Mr. Gibson (F)


Mr. Bendiksen (Sp)


Mr. Carman (W, alternate years)

157. Basic Mechanical Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 103, M105A, 105D, Civil Engineering 108, Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading.

Mr. Ghoniem, Mr. Mills (F,Sp)

157A. Fluid Mechanics and Acoustics Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 103, M105A, 105D, Civil Engineering 108, Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in heat transfer, fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading.

Mr. Ghoniem, Mr. Mills (F,Sp)


Mr. Hahn (F)


Mr. Hahn (F)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 161B. Coverage of preliminary design, students of operating spacecraft carrying a large scientific payload with modest requirements for electric power, lifetime, and attitude stability. Students work in groups of three or four, with each student responsible primarily for a subsystem and for integration of the whole. Letter grading.

Mr. Bendiksen (Sp)

161D. Space Technology Hardware Design. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Recommended requisite or corequisite: course 161B. Design, by students, of hardware with applications to space technology. Designs are then built by HSSEAS professional machine shop and tested by the students. New project carried out each year. Letter grading.

Mr. Frazzoli (W)


Mr. Yang (F,Sp)

162B. Mechanical Product Design. (4) Lecture, two hours; laboratory, four hours; outside study, four hours. Requisites: courses 94, 156A, 162A, 193, Electrical Engineering 110L. Lecture and laboratory (design course involving modern design theory and methodology for development of mechanical products. Economics, marketing, manufacturability, quality, and patentability. Design considerations taught and applied to hands-on design project. Letter grading.

Mr. Ghonieh (F,Sp)

162C. Electromechanical System Design Laboratory. (4) Lecture, one hour; laboratory, eight hours; outside study, three hours. Requisite: course 162B. Laboratory and design course consisting of design, development, construction, and testing of complex mechanical and electromechanical systems. Assembled machine is instrumented and monitored for operational characteristics. Letter grading.

Mr. Tsao (Sp)

162M. Senior Mechanical Engineering Design. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 131A, 133A, 162B, 169A, 171A. Must be taken in last two academic Semesters of students' programs. Analytical course of a large engineering system. Design factors include functionality, efficiency, economy, safety, reliability, aesthetics, and social impact. Final report of engineering specifications and drawings to be presented by design teams. Letter grading. Mr. Yang (W,Sp)

163A. Introduction to Computer-Controlled Machines. (4) Lecture, four hours; outside study, eight hours. Requisite or corequisite: course 171A. Modeling of computer-controlled machines, including electrical and electronic elements, mechanical elements, actuators, sensors, and overall electromechanical systems. Motion and command generation, servocontroller design, and computer/machine interfacing. Letter grading.

Mr. Tsao (F)

166A. Analysis of Flight Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: Civil Engineering 108. Introduction to two-dimensional elasticity, stress-strain laws, yield and fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled cross sections: shear flow, shear-lag; combined bending torsion of thin-walled, stiffened structures used in aerospace vehicles; elements of plate theory; buckling of columns. Letter grading.

Mr. Klug (F)

167.
166C. Design of Composite Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, failure analysis, design examples and design studies, buckling of composite components, nonsymmetric laminates, micromechanics of composites. Letter grading.

Mr. Carman (W)

168. Introduction to Finite Element Technology. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisites: course 20, Civil Engineering 108, Mathematics 33A. Recommended: courses 94 or 194, 166A. Introduction to finite element method (FEM) and its matrix formulation of computer implementation of FEM concepts; practical use of FEM code. Preprocessing and postprocessing techniques; graphics display capabilities; geometric and analysis modeling; interactive engineering systems; links with computer-aided design. Recent trends in FEM technology; design optimization. Term projects using FEM computer codes. Letter grading.

Mr. Klug (Sp)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; outside study, eight hours. Requisites: course 10 or 192A, Mathematics 33A. Recommended: course 108. Recommended: Electrical Engineering 102. Fundamentals of vibration theory and applications. Free, forced, and self-excited vibrations; transfer function 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), Mr. Ghoniem (W), Mr. C-J. Kim (F)

171A. Introduction to Feedback and Control Systems: Dynamic Systems Control I. (4) Lecture, four hours; outside study, eight hours. Requisite: course 191A or 192A or Electrical Engineering 102. Introduction to feedback principles, control systems design, and system stability. Modeling of physical systems in engineering and other fields; transform methods; controller design using Nyquist, Bode, and root locus methods; compensation and computer-aided analysis and design. Letter grading.

Mr. Shamma (F,W,Sp)


Mr. Tsao (Sp)

172. Control System Design Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisite: course 171A. Application of frequency domain design techniques for control of mechanical systems. Successful controller design requires students to formulate performance measures for control problem, experimentally identify mechanical systems, and develop uncertainty descriptions for design models. Exploration of issues concerning model uncertainty and sensor/actuator placement. Students implement control designs on flexible structures, rate gyroscopes, and inverted pendulum. Detailed reports required. Letter grading. Mr. M. Chau (W)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; outside study, eight hours. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading.

Mr. Hahn (W)

180. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) Same as Biomedical Engineering M150 and Electrical Engineering M150. Lecture, three hours; laboratory, three hours; outside study, nine hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 4A, 4B, 4L. Corequisite: course M180L. Instructor: Mr. C.-J. Kim (F)

180L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (4) (Formerly numbered Biomedical Engineering M150L and Electrical Engineering M150L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Corequisite: course M180. Instructor: Mr. C.-J. Kim (F)

182A. Mathematics of Engineering. (4) (Formerly numbered 192A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A, 33B. Methods of solving ordinary differential equations, Laplace transform, convolution, inverse; Fourier transform: properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading.

Mr. Mai (F,W,Sp)

182B. Mathematics of Engineering. (4) (Formerly numbered 192B.) Lecture, four hours; discussion, two hours; outside study, eight hours. Requisite: course 182A. Analytical methods for solving partial differential equations arising in engineering. Separation of variables, eigenvalue problems, Sturm/Liouville theory. Development and use of special functions. Representation by means of orthonormal functions; Galerkin method. Use of Green’s function and transform methods. Letter grading. Mr. Eldredge, Mr. J. Kim (Sp)


184. Introduction to Geometry Modeling. (4) (Formerly numbered 194.) Laboratory, eight hours; outside study, four hours. Requisites: courses 20, 94. Fundamentals in parametric and surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transformations, algebraic and geometric form of surfaces, analytical properties of curves and surfaces, 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.

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) (Formerly numbered 198.) Lecture, two to four hours; outside study, four to eight hours. Special topics in mechanical and aerospace engineering. May be repeated once for credit with school approval. Letter grading. Mr. Yang (Sp)

199. Directed Research in Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit. P/NP or letter grading.

Graduate Courses


231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Radiative properties of materials and radiative energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation transfer in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading. Mr. Pilon (F)

231D. Application of Numerical Methods to Transport Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisite: course 132A. Numerical techniques for solving selected problems in heat and mass transfer. Applications include free convection, boundary layer flow, two-phase flow, separated flow, flow in porous media. Effects of concentration and temperature on chemical reactions, radiation, electric and magnetic fields. Letter grading. Mr. Catton (Sp, alternate years)


231F. Advanced Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 231A. Advanced topics in heat transfer from current literature. Linear and nonlinear theories of thermal and hydrodynamic instability; variational methods in transport phenomena; phenomenological theories of turbulent heat and mass transport. Letter grading. Mr. Catton (Sp, alternate years)

231G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electrons, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equations, derivation of classical laws from Boltzmann transport equations, deviation from classical laws at small scale. Letter grading. Mr. Ju (Sp)

232B. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 132A. Formulation of general convective heat and mass transfer problem, including equilibrium and nonequilibrium chemistry. Similar and nonsimilar solutions for laminar flows; solution procedures for turbulent flows. Multicomponent diffusion. Application to hypersonic boundary layer, ablation and transpiration cooling, combustion. Letter grading. Mr. Mills (Sp)


239B. Seminar: Current Topics in Transport Phenomena. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, student presentations, and projects in areas of current interest in transport phenomena. May be repeated for credit. S/U grading.

239D. Seminar: Current Topics in Nuclear Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, student presentations, and projects in areas of current interest in nuclear engineering. May be repeated for credit. S/U grading.

239F. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, boundary layer, multiphase, variational methods, and measurement techniques. May be repeated for credit with topic change. S/U grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk–benefit trade-offs, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.

239H. Special Topics in Fusion Physics, Engineering, and Technology. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study of selected topics selected from research areas in fusion science and engineering, such as instabilities in burning plasmas, alternate fusion confinement concepts, inertial confinement fusion, fusion–fusion hybrid systems, and fusion reactor safety. May be repeated for credit with topic change. S/U grading.

CM240. Introduction to Biomechanics. (4) (Same as Biomedical Engineering CM240.) Lecture, four hours; outside study, eight hours. Requisites: courses 150H or Civil Engineering 108), 156A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

CM240. Foundations of Fluid Dynamics. (4) (Same as Biomedical Engineering CM240.) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electrons, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equations, derivation of classical laws from Boltzmann transport equations, deviation from classical laws at small scale. Letter grading. Mr. Ju (Sp)

CM250. Fluid Mechanics of Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B. In-depth study of large-scale chain mechanisms from combustion chemistry of several elements, etc. Letter grading. Mr. Smith (Sp, even years)

CM252. Advanced Engineering Acoustics. (4) Lecture, four hours; outside study, eight hours. Advanced studies in engineering acoustics, including three-dimensional wave propagation; propagation in bounded media; Ray acoustics; attenuation mechanisms in fluids. Letter grading. Mr. Eldredge

CM253. Advanced Fundamental Acoustics. (4) Lecture, four hours; outside study, eight hours. Advanced studies in physical acoustics, including wave phenomena, propagation in bounded media, radiation, absorption, reflection, scattering, standing waves, point sources. Nonlinearity, layered and moving media, multiple reflections. Inhomogeneous wave equation. Monopole, dipole, quadruple source fields from scattering inhomogeneities and turbulence; Lighthill theory; moving sources. Similarity methods. Selected detailed applications. Letter grading. Mr. Eldredge
254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 192A, 192B, 192C. Special topics in current interest in advanced aerodynamics. Examples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamics. Letter grading. Mr. Zhong

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B, 169A. Variational principles and Lagrange equations. Kinematics and dynamics of rigid bodies; procession and nutation of spinning bodies. Letter grading. Mr. Frazzoli (W)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Concepts of stability; state-space interpretation; stability determination by simulation; linearization, and Liapunov direct method; the Hamiltonian as a Liapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and nonlinear resonance. Application to mechanical systems. Letter grading. Mr. M'Closkey (Sp, odd years)

M256A. Mechanics of Deformable Solids. (4) (Formerly numbered 256A.) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Development of fundamental principles and equations of solid mechanics. Cartesian tensors; kinematics of large and small deformations; stress and strain tensors; balance laws of mass, linear momentum, and energy; constitutive relations of elasticity, thermoelasticity, and viscoelasticity for isotropic and anisotropic solids; solution of selected problems. Letter grading. Mr. Rapaport (E)

M256B. Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Solution of linear elastostatic problems using special techniques. Field equations of linear elastostatics; uniqueness of solution; Bethe/Rayleigh reciprocity relation; solution of two-dimensional problems using stress functions; stress concentration at holes and inclusions; complex variables and transform methods in elasticity; singularities at cracks and corners; stresses and strains in composites; three-dimensional problems — Kelvin, Boussinesq, and Crackell problems, boundary integral equation method. Letter grading. Mr. Dong, Mr. Mal (W)

M256C. Plasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: courses M256A, 156A. Rate-independent plasticity theory, yield functions, flow rules and thermodynamics. Classical rate-dependent viscoplasticity; Perzyna and Duval/Lions types of viscoplasticity. Thermoelasticity and creep. Return mapping algorithm for plasticity and viscoplasticity. Finite element implementations. Letter grading. Mr. Gupta (Sp)

256F. Analytical Fracture Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 156A, 156B, or 166A, and Materials Science 243A. Review of modern fracture mechanics, elementary stress analyses; analytical and numerical methods for calculation of crack tip stress intensity factors; engineering applications in stiffened structures, pressure vessels, plates, and shells. Letter grading. Mr. Gupta (Sp)

M257A. Elastodynamics. (4) (Same as Earth and Space Sciences M224A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves in unbounded isotropic, anisotropic, and dissipative solids. Half-space problems. Guided waves in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading. Mr. Mal (Sp)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive study and participation involving assign- ments in research problems leading to term paper or oral presentation (possible help from guest lecturers). Letter grading. Mr. Smith (Sp)

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid mechanics on topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability of solids. Requisite: course 156A. Letter grading.

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, dis- cussions, and student presentations and projects in areas of current interest in mechanical engineering. May be repeated for credit. S/U grading.


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

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156B. Recommended: course 166C. Constitutive relations for electro-magneto-mechanical materials, Fiber-optic sensor technology, Mie-icromacro analysis, including classical lamination theory, shear lag theory, concentric cylinder analysis, hexagonal models, and homogenization techniques as they apply to active materials. Active systems de- sign, inch-worm, and biomorph. Letter grading.

Mr. Carman (W)

263A. Analytical Foundations of Motion Control- ler. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 156A, 263A, 294. Theory of motion control for modern computer-con- trolled machines; multi-axis computer-controlled ma- chines; machine kinematics and dynamics; multiaxis motion coordination; coordinated motion with desired speed and acceleration; jerk analysis; motion com- mand generation; theory and designer of control in- terpolators; 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, dyn- amics, and control of spacecraft; spinning and dual-spin spacecraft dynamics; spinup through reso- nance, spinning rocket dynamics; environmental torques in space, modeling and model reduction of flexible space structures. Letter grading. Mr. Frazzoli (Sp, alternate years)

263C. Mechanics and Trajectory Planning of In- dustrial Robots. (4) Lecture, four hours; outside study, eight hours. Requisite: course 163A. Theory and implementation of industrial robots. Design con- siderations. Kinematic structure modeling, trajectory planning, and system dynamics. Differential motion and static forces. Individual student study projects. Letter grading. Mr. Yang (W)

263D. Advanced Robotics. (4) Lecture, four hours; outside study, eight hours. Recommended prepara- tion: courses 155, 163C, 171A, 263C. Motion plan- ning and control of articulated dynamic systems, including nonlinear joint control, experiments in joint control and multi-axes coordination, multi-body dynamics, trajectory planning, motion optimization, dynamic perfor- mance and kinematic manipulator design, kinematic re- dundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading. Mr. Hahn (Sp)


Mr. Bendiksen (W)

269B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Analysis of linear and nonlinear re- sponse of structures to dynamic loadings. Stresses and deflections in structures. Structural damping and self-induced vibrations. Letter grading. Mr. Bendiksen (alternate years)

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aerelasticity from a viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady air- loads from governing variational principles. Flow in- duced instability and response of structures. Letter grading. Mr. Bendiksen (F, alternate years)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engi- neering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Classical and modern approaches to linear systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, observability, realizability, and minimality. Stabilization design via state feedback, and observer design: separation principle. Connections with transfer function techniques. Letter grading. Mr. Gibson (Sp)

270B. Linear Optimal Control. (4) Lecture, four hours or 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 dis- crete-time systems; finite-horizon and infinite-horizon problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, observability, and detectability. Stabilization and Kalman filters. 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 varia- tional methods, Pontryagin maximum principle, Hamilton/Jacobi/Bellman equation (dynamic pro- gramming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. Mr. Meyer (Sp)


271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271A. Linear and nonlinear estimation theory, orthog- onal projection lemma, Bayesian filtering theory, con- ditional mean and risk estimators. Letter grading. Mr. Seyer (W)
271C. Stochastic Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271B. Stochastic dynamic programming, certainty equivalence principle, separation theorem, information statistics; linear-quadratic-Gaussian problem, linear-exponential-Gaussian problem. Relationship between stochastic control and robust control. Letter grading. Mr. Speyer (Sp)

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer (Sp)

M272A. Nonlinear Dynamic Systems (4) (Same as Chemical Engineering M282A and Electrical Engineering M282A) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M280A or Electrical Engineering M284A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Liapunov theory (including converse theorems), invariance, center manifold theorem, output-to-state stability and small-gain theorem. Letter grading. Mr. Shamma (Sp)

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisite: 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. Speyer (Sp)

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Methods for identification of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include transfer functions and state-space models. Discussion of applications in mechanical and aerospace engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading. Mr. Gibson (Sp)

M276. Dynamic Programming. (4) (Same as Electrical Engineering M276.) Lecture, four hours; outside study, eight hours. Recommended requisite: Electrical Engineering 232A or 236A or 238B. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. Mr. Gibson (Sp)

M280. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Biomedical Engineering M250A and Electrical Engineering M250A) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M180L. Advanced discussion of micromanufacturing processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C.-J. Kim (W)

280L. Microelectromechanical Systems (MEMS) Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisite: course 180L. Hands-on micromachining. Mask layout, cleanroom procedure, lithography, oxidation, LPCVD coatings, evaporation, wet etchings (both isotropic and anisotropic), dry etchings, process monitoring. Students fabricate simple micromechanical devices by both surface and bulk micromachining and test and characterize them. Letter grading. Mr. C.-J. Kim (W)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Basic scientific foundations of everyday micro to macro. Topics include micro fluid science, microscale heat transfer, mechanical behavior of microstructures, as well as dynamics and control of micro devices. Letter grading. Mr. M. Ho, Mr. C.-J. Kim (Sp)

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) at very small sizes. Topics can include micro fluid science, microscale heat transfer, mechanical behavior of microstructures, as well as dynamics and control of micro devices. Letter grading. Mr. M. Ho, Mr. C.-J. Kim (W)

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Principles and performance of micro transducers. Applications of using unique properties of micro transducers for distributed and real-time control of engineering systems. Associated signal processing requirements for these applications. Letter grading. Mr. M. Ho (W, alternate years)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, M105A, 105D, 182A. Introduction to fundamental physical phenomena occurring at interfaces and application of their knowledge to engineering problems. Fundamental concepts of interfacial phenomena, including surface tension, surfactants, interfacial thermodynamics, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, microfluidic and microelectromechanical systems, and biological systems. Letter grading. Mr. Pilon (F)

286. Molecular Dynamics Simulation. (4) Formerly numbered 282L. Lecture, four hours; outside study, eight hours. Preparation: computer programming experience. Requisite: courses 192A, 192C. Introduction to basic concepts and methodologies of molecular dynamics simulation. Advantages and disadvantages of this approach for various situations. Emphasis on applications in mechanical engineering, especially microscale fluid mechanics, mechanical devices, and solid mechanics problems. Letter grading. Mr. Kavehpour (W)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 14, Physics 17. Science and engineering of laser micromachining fabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (therma, mass, chemical, carrier, etc.) in laser microfabrication, state-of-the-art optics and instrumentation for laser microfabrication, applications such as rapid prototyping, surface modifications (physical/chemical), micro-machines for three-dimensional MEMS (microelectromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter grading. Mr. Zhang (Sp)


294. Computational Geometry for Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 194. Computational geometry for design and manufacturing, with special emphasis on curve and surface theory, geometric modeling of curves and surfaces, B-splines and NURBS, composite curves and surfaces, 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 194, 184. Exploration of advanced state-of-the-art concepts in Internet-based collaborative design, including software environments to connect designers over Internet, networked variable media graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mobile device-based systems, and multifunctional design collaboration and software tools to support it. Letter grading. Mr. Gadh (F).

295C. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, and design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. Mr. Gadh (F).


296B. Thermochemical Processing of Materials. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 193. Thermodynamics, heat and mass transfer, principles of material processing; phase equilibria and transitions, transport mechanisms of heat and mass, moving interfaces and heat sources, natural convection, nucleation and growth of microstructure, etc. Applications with chemical vapor deposition, infiltration, etc. Letter grading. Mr. Gohniemi, Ms. Lavine (W).


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

299A. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M299 and Electrical Engineering M248S.) Seminar, two hours; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.

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

474B. Concurrent Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: Materials Science 474A. Product design, CAD/CAM, engineering analysis integration, project management. Letter grading. Mr. Hahn (W).

474C. Total Quality Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 474B. Total quality management, statistics, probability, off-line quality control, online quality control, quality inspection. Letter grading. Mr. Hahn (Sp).


497A-497B. Field Project in Manufacturing Engineering. (4-4) Lecture, two hours. Teams of students perform detailed system analysis and plan design of manufacturing engineering systems at various manufacturing plants. In Progress (497A) and S/U or letter (497B) grading. Mr. Yang (W, 497A; Sp, 497B).

596. Directed Individual or Tutorial Studies. (1 to 12) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Usually taken after students have been advanced to candidacy. S/U grading. Prepared for oral qualifying examination. S/U grading.

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

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

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

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

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

Schoolwide Programs, Courses, and Faculty

UCLA 6426 Boelter Hall Box 951601
Los Angeles, CA 90095-1601
(310) 825-2826
http://www.engineer.ucla.edu

Professors Emeriti
Edward P. Coleman, Ph.D.
Herbert B. Nottage, Ph.D.
Allen B. Rosenstein, Ph.D.
Bonham Spence-Campbell, E.E.

Graduate Study
For information on graduate admission to the schoolwide engineering programs and requirements for the Engineer degree and certificate of specialization, see Graduate Programs, page 23.

Faculty Areas of Thesis Guidance

Professors Emeriti
Edward P. Coleman, Ph.D. (Columbia U., 1951)
Design of experimentation; operations management, environment; process of product reliability and quality
Herbert B. Nottage, Ph.D. (Case Institute of Technology, 1952)
Engineering design; biotechnology; pollution control; energy conservation, conversion, and heat and mass transfer and fluid flow processes; instrumentation; industrial engineering and automation, especially fluidics; vehicles, engines, and turbo-machinery; air-conditioning and refrigeration; inhabited environments; waste processing and reclamation; mathematical analysis of systems, cost-benefit economics
Allen B. Rosenstein, Ph.D. (UCLA, 1958)
Educational delivery systems, computer-aided design, design, automatic controls, magnetic controls, nonlinear electronics
Bonham Spence-Campbell, E.E. (Cornell, 1939)
Development of interdisciplinary engineering/social science teams and their use in planning and management of projects and systems

Lower Division Courses

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.

103
87. Introduction to Engineering Disciplines. (4) (Formerly numbered 97.) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team process. Investigation of national need underlying current effort to increase participation of historically underrepresented groups in the U.S. technological work force. P/NP grading.

95. Ethical and Professional Issues in Engineering and Computer Science. (4) Lecture, four hours; discussion, one hour. Selected lectures, discussions, and oral and written reports related to profession of engineering. Lectures by practicing engineers, case studies, and small group projects on issues that involve conflicting demands on society. Letter grading.

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

Upper Division Courses

183. Engineering and Society. (4) (Formerly numbered 193.) Lecture, four hours; discussion, one hour; outside study, seven hours. Limited to junior/senior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and on development of moral and ethical values. Contemporary environmental, biological, legal, and other issues created by new technologies. Letter grading.

195. Internship Studies in Engineering. (4) (Formerly numbered 195I.) Tutorial, four hours. Limited to juniors/seniors. Internship studies course supervised by associate dean or designated faculty members. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be applied toward major requirements. Normally, only 4 units of internship are allowed. Individual contract with associate dean required. P/NP grading.

Mr. Jacobsen (F,W,Sp)

Graduate Courses

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading.

Mr. Jacobsen (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.

Mr. Jacobsen (F,W,Sp)

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

Mr. Jacobsen (F,W,Sp)


471A-471B. The Engineer in the General Environment. (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading; In Progress (471B) and S/U or letter (471C) grading.

472A-472D. The Engineer in the Business Environment. (3-3-3-1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Language of business for the engineering executive. Accounting, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (472A, 472C) and S/U or letter grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of a Large-Scale System. (3-3-3-1.5) Lecture, two and one-half hours. Limited to Engineering Executive Program students. Premise area of master's program. Project also serves as laboratory in organization for a goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Used to record enrollment of UCLA students in courses taken under cooperative arrangements with USC. S/U grading.
Artificial Intelligence Laboratory
Michael G. Dyer (Computer Science), Director
The Artificial Intelligence (AI) Laboratory was established in 1984 to support graduate research and education in the following areas:
Natural language processing (NLP). Computer comprehension and generation of text (e.g., short stories, editorials, and dialogs). Related tasks include question answering, paraphrasing, and machine translation of natural language texts.
Cognitive modeling. Simulation of high-level cognitive functions, including representation of thought, machine learning, creativity and invention, planning and goal analysis, role of emotion in high-level cognition, modeling of human memory, argumentation and belief analysis, moral judgment and legal reasoning, naive physics, humor (e.g., irony), and abstract theme analysis.
Application of artificial neural network technology to modeling high-level cognitive tasks. Mechanisms include parallel distributed processing (PDP) approaches, tensor networks, self-organizing feature maps, recurrent backpropagation, localist spreading activation networks, and hybrid symbolic/neural models. Tasks include NLP, language acquisition, and symbol grounding (i.e., relating language to perceptual information).
Evolution of language and communication. Use of genetic algorithms (i.e., mutation and recombination of artificial genomes) to evolve populations of artificial neural networks that communicate and cooperate to accomplish survival-based tasks, such as mate-finding, food gathering, and nest construction.
Other AI faculty members within the Computer Science Department direct research in the areas of heuristic search and distributed AI, game playing, decision-making and Bayesian networks, neural modeling, machine vision, and expert systems.

Center for Environmental Risk Reduction
Yoram Cohen (Chemical Engineering), Director, http://www.cerr.ucla.edu
The Center for Environmental Risk Reduction (CERR) is a multidisciplinary research center established in 1995. The objective of the center is to develop and evaluate risk reduction and pollution prevention technologies and strategies. The CERR focuses its research activities in a number of key areas such as:
1. Multimedia studies of the transport, exposure, and health risks associated with environmental contaminants. Fundamental research is stressed, with emphasis on transport process modeling, biochemical transformation, exposure modeling and monitoring.
2. Evaluation and development of strategies and technologies for risk reduction and pollution prevention, including recovery and recycle of trace-level contaminant, product and raw material substitution, and policy-driven strategies.
The CERR includes student and faculty members from HSSEAS.

Center for High-Frequency Electronics
See Electrical Engineering Department

Flight Systems Research Center
A.V. Balakrishnan (Electrical Engineering), Director; Kenneth W. Iliff (Electrical Engineering), Associate Director, http://fsrc.ee.ucla.edu
The Flight Systems Research Center, established in 1985 under a Memorandum-of-Agreement with the NASA Ames/Dryden Flight Research Facility, is devoted to interdisciplinary research in flight systems and related technologies. Faculty from the Atmospheric Sciences, Computer Science, Electrical Engineering, Mathematics, and Mechanical and Aerospace Engineering Departments are currently associated with the center. Current research projects include:
- Estimation of wind profiles from laser-beam propagation distortion
- Probabilistic risk assessment and management
- Modeling of high mach number flows for Pegasus
- Leading-edge cooling
- Modeling, identification, and control with applications to flight vehicles

Institute of Plasma and Fusion Research
Mohamed A. Abdou (Engineering) and Alfred Wong (Physics), Codirectors, http://www.ipfr.ucla.edu
The Institute of Plasma and Fusion Research is a UCLA organized research unit dedicated to research into plasma physics, fusion energy, and the applications of plasmas in other areas of science and engineering. Students, professional research staff, and faculty, generally working in groups, study basic laboratory plasmas, plasma/fusion confinement experiments, fusion engineering and nuclear technology, computer simulations and the theory of plasmas, advanced plasma diagnostic development, laser/plasma interactions, and the use of plasma in applications ranging from particle accelerators to the processing of materials and surfaces used in microelectronics or for coatings.
The institute and its members are affiliated with both the College of Letters and Science and the Henry Samueli School of Engineering and Applied Science. Faculty, staff, and students come from the Electrical Engineering, Mechanical and Aerospace Engineering, and Physics and Astronomy Departments.
The overall UCLA effort in this field is quite broad. On a disciplinary basis, the program can be divided into the following categories:
- Astrophysical and space plasmas
- Basic plasma experiments
- Computer simulation of plasmas
- Fluid and thermal engineering sciences for fusion technology
- Fusion confinement experiments and devices
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, UCLAs plasma and fusion programs received more than $12 million in research grants from several federal agencies, from the National Laboratories, and from industry. The largest amount of funding comes from the U.S. Department of Energy, but substantial resources are received from the National Science Foundation, NASA, and research offices of the U.S. Department of Defense.

**Nanoelectronics Research Facility**

See Electrical Engineering Department
## FRESHMAN YEAR

### 1st Quarter
- Chemistry and Biochemistry 20A  Chemical Structure ........................................... 4
- English Composition 3  English Composition, Rhetoric, and Language ......................... 5
- Mathematics 31A  Differential Calculus .......................................................... 4
- Mathematics 31B  Integration and Infinite Series ................................................. 4
- Mechanical and Aerospace Engineering 154A  Preliminary Design of Aircraft ............ 4
- Mechanical and Aerospace Engineering 154B  Design of Aerospace Structures .......... 4
- Mechanical and Aerospace Engineering 157A  Basic Mechanical Engineering Laboratory 4
- Mechanical and Aerospace Engineering 157  Basic Mechanical Engineering Laboratory 4
- Mechanical and Aerospace Engineering 150D  Transport Phenomena ......................... 4
- Mechanical and Aerospace Engineering 102  Mechanics of Particles and Rigid Bodies 4
- Mechanical and Aerospace Engineering 150B  Aerodynamics .................................. 4
- Mechanical and Aerospace Engineering 182A  Mathematics of Engineering ................. 4
- Mechanical and Aerospace Engineering 154S  Flight Mechanics, Stability, and Control of Aircraft 4
- Mechanical and Aerospace Engineering 150A  Intermediate Fluid Mechanics ............ 4
- Mechanical and Aerospace Engineering 157B  Basic Mechanical Engineering Laboratory 4
- Mechanical and Aerospace Engineering 157  Basic Mechanical Engineering Laboratory 4
- Mechanical and Aerospace Engineering 150P  Aircraft Propulsion Systems ............... 4
- Mechanical and Aerospace Engineering 154S  Flight Mechanics, Stability, and Control of Aircraft 4
- Mechanical and Aerospace Engineering 154A  Preliminary Design of Aircraft .......... 4
- Aerospace Engineering Electives (2)‡ ............................................................... 8
- HSSEAS GE Elective* .......................................................................................... 4

### 2nd Quarter
- Mathematics 31A  Differential Calculus .......................................................... 4
- Mathematics 31B  Integration and Infinite Series ................................................. 4
- Mechanical and Aerospace Engineering 154A  Preliminary Design of Aircraft ............ 4
- Mechanical and Aerospace Engineering 154B  Design of Aerospace Structures .......... 4
- Mechanical and Aerospace Engineering 157A  Basic Mechanical Engineering Laboratory 4
- Mechanical and Aerospace Engineering 150D  Transport Phenomena ......................... 4
- Mechanical and Aerospace Engineering 154S  Flight Mechanics, Stability, and Control of Aircraft 4
- Mechanical and Aerospace Engineering 150A  Intermediate Fluid Mechanics ............ 4
- Mechanical and Aerospace Engineering 154A  Preliminary Design of Aircraft .......... 4
- Aerospace Engineering Electives (2)‡ ............................................................... 8
- HSSEAS GE Elective* .......................................................................................... 4

### 3rd Quarter
- Mathematics 32B  Calculus of Several Variables ................................................. 4
- Physics 1C  Electrodynamics, Optics, and Special Relativity ................................. 5
- Physics 4BL  Electricity and Magnetism Laboratory .............................................. 2
- HSSEAS GE Elective* .......................................................................................... 4
- Materials Science and Engineering 14  Science of Engineering Materials ............... 4
- Mathematics 33A  Linear Algebra and Applications .............................................. 4
- Mechanical and Aerospace Engineering M105A  Introduction to Engineering Thermodynamics 4
- HSSEAS GE Elective* .......................................................................................... 4

### HSSEAS GE Elective
- Physics 1C  Electrodynamics, Optics, and Special Relativity ................................. 5
- Mathematics 32B  Calculus of Several Variables ................................................. 4
- Electrical Engineering 100  Electrical and Electronic Circuits .............................. 4
- Mechanical and Aerospace Engineering 102  Mechanics of Particles and Rigid Bodies 4
- Mechanical and Aerospace Engineering 103  Elementary Fluid Mechanics ............. 4
- Mechanical and Aerospace Engineering 105D  Transport Phenomena ......................... 4
- Mechanical and Aerospace Engineering 150A  Intermediate Fluid Mechanics ............ 4
- Mechanical and Aerospace Engineering 161A  Introduction to Astronautics † or Aerospace Engineering Elective‡ .......................................................... 4
- Mechanical and Aerospace Engineering 169A  Introduction to Mechanical Vibrations † or Aerospace Engineering Elective‡ .......................................................... 4
- HSSEAS GE Elective* .......................................................................................... 4

### JUNIOR YEAR

### 1st Quarter
- Civil and Environmental Engineering 108  Introduction to Mechanics of Deformable Solids 4
- Electrical Engineering 100  Electrical and Electronic Circuits .............................. 4
- Mechanical and Aerospace Engineering 105D  Transport Phenomena ......................... 4
- Mechanical and Aerospace Engineering 182A  Mathematics of Engineering ................. 4
- Mechanical and Aerospace Engineering 150A  Intermediate Fluid Mechanics ............ 4
- Mechanical and Aerospace Engineering 157  Basic Mechanical Engineering Laboratory 4
- Mechanical and Aerospace Engineering 169A  Introduction to Mechanical Vibrations † or Aerospace Engineering Elective‡ .......................................................... 4
- HSSEAS GE Elective* .......................................................................................... 4
- Electrical Engineering 102  Systems and Signals ................................................... 4
- Mechanical and Aerospace Engineering 150B  Aerodynamics .................................. 4
- Mechanical and Aerospace Engineering 171A  Introduction to Feedback and Control Systems 4
- Mathematics Elective* ......................................................................................... 4

### 2nd Quarter
- Mechanical and Aerospace Engineering 150P  Aircraft Propulsion Systems ............... 4
- Mechanical and Aerospace Engineering 154S  Flight Mechanics, Stability, and Control of Aircraft 4
- Mechanical and Aerospace Engineering 161A  Introduction to Astronautics † or Aerospace Engineering Elective‡ .......................................................... 4
- Mechanical and Aerospace Engineering 166A  Analysis of Flight Structures .............. 4
- Aerospace Engineering Electives (2)‡ ............................................................... 8
- HSSEAS GE Elective* .......................................................................................... 4

### 3rd Quarter
- Mechanical and Aerospace Engineering 154B  Design of Aerospace Structures ............ 4
- Mechanical and Aerospace Engineering 157A  Fluid Mechanics and Aerodynamics Laboratory 4
- Aerospace Engineering Elective‡ .......................................................................... 4
- HSSEAS GE Elective* .......................................................................................... 4

## SENIOR YEAR

### 1st Quarter
- Mechanical and Aerospace Engineering 150A  Intermediate Fluid Mechanics ............ 4
- Mechanical and Aerospace Engineering 154S  Flight Mechanics, Stability, and Control of Aircraft 4
- Mechanical and Aerospace Engineering 161A  Introduction to Astronautics † or Aerospace Engineering Elective‡ .......................................................... 4
- Mechanical and Aerospace Engineering 166A  Analysis of Flight Structures .............. 4
- Aerospace Engineering Electives (2)‡ ............................................................... 8
- HSSEAS GE Elective* .......................................................................................... 4

### 2nd Quarter
- Mechanical and Aerospace Engineering 154A  Preliminary Design of Aircraft ............ 4
- Mechanical and Aerospace Engineering 154B  Design of Aerospace Structures ............ 4
- Aerospace Engineering Electives (2)‡ ............................................................... 8
- HSSEAS GE Elective* .......................................................................................... 4

### 3rd Quarter
- Mechanical and Aerospace Engineering 154B  Design of Aerospace Structures ............ 4
- Mechanical and Aerospace Engineering 157A  Fluid Mechanics and Aerodynamics Laboratory 4
- Aerospace Engineering Elective‡ .......................................................................... 4
- HSSEAS GE Elective* .......................................................................................... 4

## TOTAL

191

*Students should contact the Office of Academic and Student Affairs for approved elective lists in the categories of mathematics and HSSEAS GE (see page 21 for details).

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

‡A total of 16 units of aerospace engineering electives (four courses) is required; electives must be selected so that the program contains a total of at least 24 design units.
# B.S. in Bioengineering Curriculum

## FRESHMAN YEAR

### 1st Quarter
- Bioengineering 1* Chemistry and Biochemistry Laboratory I
- Chemistry and Biochemistry 14A** Chemical Structures and Equilibria
- Mathematics 31A Differential Calculus

### 2nd Quarter
- Bioengineering 10 Introduction to Bioengineering (2)
- Chemistry and Biochemistry 14B Thermodynamics, Kinetics, Organic Structures, and Spectroscopy
- Mathematics 31B Integration and Infinite Series

### 3rd Quarter
- Bioengineering 3* Introduction to Biophysics III/Biophysics Laboratory III
- Chemistry and Biochemistry 14C** Organic Molecular Structures and Interactions
- Mathematics 32A Calculus of Several Variables

## SOPHOMORE YEAR

### 1st Quarter
- Bioengineering 100 Bioengineering Fundamentals
- Chemistry and Biochemistry 14BL** General and Organic Chemistry Laboratory I
- Mathematics 32B Calculus of Several Variables

### 2nd Quarter
- Chemistry and Biochemistry 14CL** General and Organic Chemistry Laboratory II
- Mathematics 33A Linear Algebra and Applications
- Mechanical and Aerospace Engineering 20 Programming with Numerical Methods Applications
- HSSEAS GE Elective†

### 3rd Quarter
- Chemical Engineering M105A Introduction to Engineering Thermodynamics
- Chemistry and Biochemistry 14D** Organic Reactions, Pharmaceutical Structures, and Activities
- Life Sciences 2 Cells, Tissues, and Organs
- Mathematics 33B Differential Equations

## JUNIOR YEAR

### 1st Quarter
- Chemical Engineering 101A Momentum Transfer
- Chemistry and Biochemistry 110A Physical Chemistry: Chemical Thermodynamics
- Chemistry and Biochemistry 153A Biochemistry: Introduction to Structure, Enzymes, and Metabolism
- Life Sciences 3 Introduction to Molecular Biology

### 2nd Quarter
- Bioengineering 110 Biotransport and Bioreaction Processes
- Chemistry and Biochemistry 156 Physical Biochemistry
- Electrical Engineering 102 (Systems and Signals) or Mathematics 115A (Linear Algebra)
- Life Sciences 4 Genetics

### 3rd Quarter
- Bioengineering 120 Biomedical Transducers
- Biomedical Engineering M186B Computational Systems Biology: Modeling and Simulation of Biological Systems
- Molecular, Cell, and Developmental Biology M140 Cell Biology: Cell Cycle
- HSSEAS GE Elective†

## SENIOR YEAR

### 1st Quarter
- Bioengineering 176 Principles of Biocompatibility
- Bioengineering 180/180L System Integration in Biology, Engineering, and Medicine I/Laboratory
- Bioengineering 182 Bioengineering Capstone Design I
- HSSEAS GE Elective†

### 2nd Quarter
- Bioengineering 181/181L System Integration in Biology, Engineering, and Medicine II/Laboratory
- Bioengineering 182B Bioengineering Capstone Design II
- Biomedical Engineering Elective†
- HSSEAS GE Elective†

### 3rd Quarter
- Bioengineering 165 Bioethics and Regulatory Policies in Bioengineering
- Bioengineering 182C Bioengineering Capstone Design III
- Biomedical Engineering Elective†
- HSSEAS GE Electives (2)†

## TOTAL

198

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*Physics 1A, 1B, 1C (or Electrical Engineering 1), 4AL, and 4BL may be substituted for courses 1, 1L, 2, 2L, and 3.

**Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, and 30B may be substituted for the Chemistry and Biochemistry 14 series.

†See page 21 for details.

‡See page 25 for list of approved electives.
# B.S. in Chemical Engineering Curriculum

## FRESHMAN YEAR

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<thead>
<tr>
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<th>Course Title</th>
<th>Units</th>
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<tr>
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<td>Physics 1A</td>
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<td>Chemistry and Biochemistry 30A</td>
<td>Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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<td>Chemistry and Biochemistry 30AL</td>
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<td>Physics 1B/4AL</td>
<td>Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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## SOPHOMORE YEAR

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<td>Organic Chemistry: Reactivity and Synthesis, Part I/Laboratory I</td>
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<td>Physics 1C</td>
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<td>Chemical Engineering M105A</td>
<td>Introduction to Engineering Thermodynamics</td>
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<td>Chemistry and Biochemistry 171</td>
<td>Intermediate Inorganic Chemistry</td>
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<td>Chemical Engineering 108</td>
<td>Process Economics and Analysis</td>
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<td>Chemical Engineering 107</td>
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## JUNIOR YEAR

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<td>Chemical Engineering 101A</td>
<td>Momentum Transfer</td>
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<td>Chemical Engineering 109</td>
<td>Mathematical Methods in Chemical Engineering</td>
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<td>Chemistry and Biochemistry 113A</td>
<td>Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Electrical Engineering 100</td>
<td>Electrical and Electronic Circuits</td>
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<td>2nd Quarter</td>
<td>Chemical Engineering 101B</td>
<td>Heat Transfer</td>
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<td>Chemical Engineering 102</td>
<td>Chemical Engineering Thermodynamics</td>
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<td>Chemical Engineering 101C</td>
<td>Mass Transfer</td>
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<td>Chemical Engineering 103</td>
<td>Separation Processes</td>
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<td>Chemical Engineering 104A</td>
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## SENIOR YEAR

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<td>Chemical Engineering Laboratory II</td>
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<td>Chemical Engineering 106</td>
<td>Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107</td>
<td>Process Dynamics and Control</td>
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<td>Chemical Engineering 108A</td>
<td>Process Economics and Analysis</td>
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<td>HSSEAS GE Elective</td>
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<tr>
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<td>Chemical Engineering 108B</td>
<td>Chemical Process Computer-Aided Design and Analysis</td>
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**TOTAL** 198

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*See page 21 for details.

†Chemistry elective may be replaced by any upper division life or physical sciences course with approval of adviser; one chemistry elective may be replaced by any upper division life or physical sciences course with approval of adviser; Chemistry and Biochemistry 110A is highly recommended.

‡Suggested electives include Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C123, C140.
# B.S. in Chemical Engineering
## Bioengineering Option Curriculum

### FRESHMAN YEAR

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<th>Course Description</th>
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<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A, Chemical Structure</td>
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<td>English Composition 3, English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A, Differential Calculus</td>
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<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B, Chemical Energetics and Change</td>
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<tr>
<td>2nd Quarter</td>
<td>Mathematics 31B, Integration and Infinite Series</td>
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<tr>
<td>3rd Quarter</td>
<td>Physics 1A, Mechanics</td>
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</tr>
<tr>
<td>3rd Quarter</td>
<td>HSSEAS GE Elective*</td>
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### SOPHOMORE YEAR

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<th>Course Description</th>
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<tr>
<td>1st Quarter</td>
<td>Chemical Engineering 100, Introduction to Chemical Engineering</td>
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<td>Chemistry and Biochemistry 30AL, General Chemistry Laboratory II</td>
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<td>Mathematics 32B, Calculus of Several Variables</td>
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<tr>
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<td>Physics 1C/4BL, Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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<td>2nd Quarter</td>
<td>Chemical Engineering M106A, Introduction to Engineering Thermodynamics</td>
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<td>Chemistry and Biochemistry 30B/30BL, Organic Chemistry: Reactivity and Synthesis, Part III, Laboratory I</td>
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<td>Civil and Environmental Engineering 15, Introduction to Computing for Civil Engineers</td>
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### JUNIOR YEAR

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<th>Course Description</th>
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<td>Chemical Engineering 101A, Momentum Transfer</td>
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<td>Chemical Engineering 109, Mathematical Methods in Chemical Engineering</td>
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<td>1st Quarter</td>
<td>Chemistry and Biochemistry 156, Physical Biochemistry</td>
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<td>1st Quarter</td>
<td>Life Sciences 3, Introduction to Molecular Biology</td>
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<td>2nd Quarter</td>
<td>Chemical Engineering 101B, Heat Transfer</td>
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<td>2nd Quarter</td>
<td>Chemical Engineering 102, Chemical Engineering Thermodynamics</td>
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<tr>
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<td>Life Sciences 4 (Genetics) or Microbiology, Immunology, and Molecular Genetics 101 (Introductory Microbiology)</td>
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### SENIOR YEAR

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<td>Chemical Engineering 101C, Mass Transfer</td>
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<td>Chemical Engineering 103, Separation Processes</td>
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<td>Chemical Engineering 104A, Chemical Engineering Laboratory I</td>
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<td>Bioengineering Elective†</td>
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**TOTAL** 204 or 205

*See page 21 for details.
†Recommended electives are Chemical Engineering C115, C125, CM145. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.
‡Biology elective is selected from any upper division course in Ecology and Evolutionary Biology or Molecular, Cell, and Developmental Biology or Microbiology, Immunology, and Molecular Genetics, provided the course requires one year of chemistry as a requisite.
## B.S. in Chemical Engineering

### Biomedical Engineering Option Curriculum

#### FRESHMAN YEAR

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#### SOPHOMORE YEAR

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#### JUNIOR YEAR

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<td>HSSEAS GE Electives (2)*</td>
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| Total | 203 or 204 |

*See page 21 for details.
†Biological elective is selected from any upper division course in Biology or Molecular, Cell, and Developmental Biology or Microbiology, Immunology, and Molecular Genetics, provided the course requires one year of chemistry as a prerequisite.
‡Recommended electives are Chemical Engineering C115, C125, CM145. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.

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# B.S. in Chemical Engineering
## Environmental Option Curriculum

### Freshman Year

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<td>Civil and Environmental Engineering 15, Introduction to Computing for Civil Engineers</td>
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<td>Chemistry and Biochemistry 113A, Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 101B, Heat Transfer</td>
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### Total

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*See page 21 for details.
‡Suggested advanced chemistry electives in the environmental field are Atmospheric and Oceanic Sciences M203A, Chemistry and Biochemistry 103, 110B, Ecology and Evolutionary Biology M127, and Environmental Health Sciences 240, 261. Other advanced chemistry courses may be selected in consultation with the faculty adviser.
¶Recommended electives are Chemical Engineering 113, C118, C119, C140. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.
### FRESHMAN YEAR

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### SOPHOMORE YEAR

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### JUNIOR YEAR

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### TOTAL

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‡Chemistry elective can be any upper division chemistry course except Chemistry and Biochemistry 110A and should be selected in consultation with adviser; Chemistry and Biochemistry 110B is highly recommended.

†Suggested electives include Chemical Engineering C112, 113, C114, C116, C118, C119, C140. Another chemical engineering elective may be substituted for one of these with approval of the faculty adviser.
# B.S. in Civil Engineering Curriculum

## FRESHMAN YEAR

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## SOPHOMORE YEAR

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## JUNIOR YEAR

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## SENIOR YEAR

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*See page 21 for details.
†At least one major field elective must include a major design project (selected from Civil and Environmental Engineering 135L, 144, 147, 157B, 157C, 157L), and at least 8 units of laboratory in at least two major field areas are required.
# B.S. in Computer Science Curriculum

## Freshman Year

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<td>CS M151B or EE M116C</td>
<td>Computer Systems Architecture</td>
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<td>CS 180</td>
<td>Introduction to Algorithms and Complexity</td>
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<td>CS M152B or EE M116D</td>
<td>Digital Design Project Laboratory</td>
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<td>CS 161</td>
<td>Fundamentals of Artificial Intelligence</td>
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<td>CS 111</td>
<td>Operating Systems Principles</td>
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## Senior Year

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<td>Computer Network Fundamentals</td>
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<td>CS 181</td>
<td>Introduction to Formal Languages and Automata Theory</td>
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<td>CS 132</td>
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**TOTAL** 182

*See page 21 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.

*Students who select Electrical Engineering 103 may not receive credit for Mathematics 151A under the technical minor.
# B.S. in Computer Science and Engineering Curriculum

## FRESHMAN YEAR

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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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<td>Computer Science 32. Introduction to Computer Science II</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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## SOPHOMORE YEAR

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<td>Mathematics 32B. Calculus of Several Variables</td>
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<td>Mathematics 61. Introduction to Discrete Structures</td>
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<td>Physics 4BL. Electricity and Magnetism Laboratory</td>
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<td>HSSEAS GE Electives*</td>
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<tr>
<td>Computer Science M152A or Electrical Engineering M116L. Introductory Digital Design Laboratory</td>
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<tr>
<td>Electrical Engineering 2. Physics for Electrical Engineers</td>
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<td>Electrical Engineering 10. Circuit Analysis I</td>
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<td>Mathematics 33B. Differential Equations</td>
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## JUNIOR YEAR

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<td>Computer Science 131. Programming Languages</td>
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<td>Computer Science 111. Operating Systems Principles</td>
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<td>Electrical Engineering 103. Applied Numerical Computing</td>
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<td>Electrical Engineering 115AL. Analog Electronics Laboratory I</td>
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## SENIOR YEAR

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**TOTAL: 186**

*See page 21 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.*
# B.S. in Electrical Engineering Curriculum

## Freshman Year

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## Sophomore Year

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## Junior Year

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## Senior Year

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<td>Electrical Engineering 172</td>
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 total: 190

*See page 21 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.

†Course must be selected from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A).
### B.S. in Electrical Engineering

#### Biomedical Engineering Option Curriculum

**FRESHMAN YEAR**

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<td>Chemistry and Biochemistry 20B/20L  Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B  Integration and Infinite Series</td>
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<td>Life Sciences 1  Evolution, Ecology, and Biodiversity</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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**JUNIOR YEAR**

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<td>Electrical Engineering 102  Systems and Signals</td>
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<td>Electrical Engineering 103  Applied Numerical Computing</td>
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<td>Electrical Engineering 110  Circuit Analysis II</td>
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<td>Electrical Engineering 110L  Circuit Measurements Laboratory</td>
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<td>Electrical Engineering 121B  Principles of Semiconductor Device Design</td>
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<td>Life Sciences 3  Introduction to Molecular Biology</td>
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<td>Mathematics 113 (Combinatorics) or 132 (Complex Analysis for Applications)</td>
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<td>Mechanical and Aerospace Engineering 103  Elementary Fluid Mechanics</td>
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<td>Electrical Engineering 113  Digital Signal Processing</td>
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<td>Mechanical and Aerospace Engineering 182A  Mathematics of Engineering</td>
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**SENIOR YEAR**

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<td>Electrical Engineering 161  Electromagnetic Waves</td>
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<td>Electrical Engineering 114D  Speech and Image Processing Systems Design</td>
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<td>Electrical Engineering 132A  Introduction to Communication Systems</td>
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<td>Chemistry and Biochemistry 30A  Chemical Dynamics and Reactivity: Introduction to Organic Chemistry</td>
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**TOTAL** 201

*See page 21 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.
†See counselor, 6426 Boelter Hall, for details.
‡See page 48, Biomedical Engineering Option, item 3, for list of approved electives.
# B.S. in Electrical Engineering
## Computer Engineering Option Curriculum

### FRESHMAN YEAR

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<td>Introduction to Computer Science I</td>
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<td>1st</td>
<td>Mathematics 31A</td>
<td>Differential Calculus</td>
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<td>Introduction to Computer Science II</td>
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<td>English Composition, Rhetoric, and Language</td>
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<td>Computer Science 33</td>
<td>Introduction to Computer Organization</td>
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<td>Physics 1B</td>
<td>Oscillations, Waves, Electric and Magnetic Fields</td>
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### SOPHOMORE YEAR

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<td>Electrical Engineering M16 or Computer Science M51A</td>
<td>Logic Design of Digital Systems</td>
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<td>Mathematics 33A</td>
<td>Linear Algebra and Applications</td>
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<td>Electricity and Magnetism Laboratory</td>
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<td>Electrical Engineering 10</td>
<td>Circuit Analysis I</td>
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<td>Mathematics 33B</td>
<td>Differential Equations</td>
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### JUNIOR YEAR

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<td>Circuit Measurements Laboratory</td>
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<td>Analog Electronic Circuits I</td>
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<td>Electrical Engineering M116C or Computer Science M151B</td>
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<td>Principles of Semiconductor Device Design</td>
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<td>Operating Systems Principles</td>
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<td>Analog Electronics Laboratory I</td>
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### SENIOR YEAR

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**TOTAL** 190

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*See page 21 for details; a course in ethics and professionalism is required as part of the HSSEAS general education requirements.
†Course must be selected from Materials Science and Engineering 14, Mechanical and Aerospace Engineering 102, 103, M105A (or Chemical Engineering M105A).
‡See page 88, Computer Engineering Option, item 3, for list of approved electives.
# B.S. in Materials Engineering Curriculum

## Freshman Year

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<td>Materials Science and Engineering 10  Freshman Seminar: New Materials</td>
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<td>Mathematics 31A  Differential Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L  Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B  Integration and Infinite Series</td>
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<td>Civil and Environmental Engineering 15 (Introduction to Computing for Civil Engineers) or Computer Science 31 (Introduction to Computer Science I) or Mechanical and Aerospace Engineering 20 (Programming with Numerical Methods Applications)</td>
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<td>Materials Science and Engineering 14  Science of Engineering Materials</td>
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<td>Materials Science and Engineering 120  Physics of Materials</td>
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<td>Materials Science and Engineering 131/131L  Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>Materials Science and Engineering 143A  Mechanical Behavior of Materials</td>
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<td>Materials Science and Engineering 132  Structure and Properties of Metallic Alloys</td>
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## Senior Year

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<td>Materials Science and Engineering 141L  Computer Methods and Instrumentation in Materials Science</td>
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<td>Materials Science and Engineering 150  Introduction to Polymers</td>
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<td>Materials Science and Engineering 140  Materials Selection and Engineering Design</td>
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<td>Materials Science and Engineering 161L  Laboratory in Ceramics</td>
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**Total** 182 or 183

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*See page 21 for details.
†See page 84, B.S. in Materials Engineering, item 4, for list of approved electives.
# B.S. in Materials Engineering
## Electronic Materials Option Curriculum

### FRESHMAN YEAR

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<td>Introduction to Computer Science I</td>
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<td>Oscillations, Waves, Electric and Magnetic Fields</td>
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<tbody>
<tr>
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<td>Science of Engineering Materials</td>
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<td>Calculus of Several Variables</td>
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<td>Mathematics 33A</td>
<td>Linear Algebra and Applications</td>
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<td>Mechanical and Aerospace Engineering M105A</td>
<td>Introduction to Engineering Thermodynamics</td>
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<td>Electrical Engineering 10</td>
<td>Circuit Analysis I</td>
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<td>Fundamentals of Solid-State I</td>
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<td>Introduction to Materials Characterization A/Laboratory</td>
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<td>Phase Relations in Solids</td>
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<td>Electrical Engineering 101</td>
<td>Engineering Electromagnetics</td>
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<td>Fundamentals of Solid-State II</td>
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<td>Materials Science and Engineering 122</td>
<td>Principles of Electronic Materials Processing</td>
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<td>Electrical Engineering 121B</td>
<td>Principles of Semiconductor Device Design</td>
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<td>Electronic Materials Major Field Elective*</td>
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<td>Electronic Materials Technical Electives (2)</td>
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**TOTAL** 195 or 196

*See page 21 for details.
†Select two courses from Materials Science and Engineering 132, 150, 160.
# B.S. in Mechanical Engineering Curriculum

## FRESHMAN YEAR

<table>
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## SOPHOMORE YEAR

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<td>Mechanical and Aerospace Engineering 94  Introduction to Computer-Aided Design and Drafting</td>
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<td>Physics 1C  Electrodynamics, Optics, and Special Relativity</td>
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## JUNIOR YEAR

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<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 108  Introduction to Mechanics of Deformable Solids</td>
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<td>Electrical Engineering 100  Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 105D  Transport Phenomena</td>
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<td>Mechanical and Aerospace Engineering 157  Basic Mechanical Engineering Laboratory</td>
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<td>Mechanical and Aerospace Engineering 169A  Introduction to Mechanical Vibrations</td>
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<td>Mechanical and Aerospace Engineering 171A  Introduction to Feedback and Control Systems</td>
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<td>Mechanical and Aerospace Engineering 162B  Mechanical Product Design</td>
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**TOTAL: 193**

*See page 21 for details.*
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http://www.gdnet.ucla.edu
International Students and Scholars, Office of, 106 Bradley Hall
http://www.intl.ucla.edu
Housing: Community Housing Office, 360 De Neve Drive
http://www.cho.ucla.edu
UCLA Housing Assignment Office, 360 De Neve Drive
http://www.housing.ucla.edu/myhousing/
Office of the President, Admissions
http://www.universityofcalifornia.edu/admissions/welcome.html
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http://www.registrar.ucla.edu
Summer Sessions, 1147 Murphy Hall
http://www.summer.ucla.edu
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http://www.chemeng.ucla.edu
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http://www.cee.ucla.edu
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http://www.cs.ucla.edu
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http://www.ee.ucla.edu
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http://www.materials.ucla.edu
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http://www.uclaextension.edu
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General Counseling, Michel Moraga, (310) 825-5760, michel@ea.ucla.edu
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