Since it welcomed its first students in 1945, the UCLA Henry Samueli School of Engineering and Applied Science has been at the forefront of advanced interdisciplinary research and engineering education. Among its notable achievements, the school is well-known as the birthplace of the Internet, for developing the first reverse-osmosis membrane for the desalination of water, for major contributions to the development of technologies underlying mobile devices, and for many other activities that have led to new breakthroughs and changed the way we interact with the world around us.

Our faculty members and their students are leaders in new frontiers of applied science and engineering research, in emerging areas such as clean and renewable energy, clean water technology, personalized healthcare, wireless sensing and sensor systems, cybersecurity, information technology, bioengineering, nanomanufacturing, microelectromechanical and nanoelectromechanical systems, and nanoelectronics.

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

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

Students may choose to work with individual faculty members or to participate in any of the school’s world-class interdisciplinary research centers. These include the NSF-funded Center for Translational Applications of Nanoscale Multiferroic Systems, SRC Focus Center on Function Accelerated nanoMaterial Engineering, NRI Western Institute of Nanoelectronics, DOE-funded Center for Molecularly Engineered Energy Materials, NSF Center for Domain-Specific Computing, Smart Grid Energy Research Center, Wireless Health Institute, and NSF Named Data Networking Project. We encourage students to spend one summer as interns in industry. Our faculty members and students are also active partners in the California NanoSystems Institute located at UCLA. In addition, the school is developing its research breakthroughs into the commercial sector through the off-campus Institute for Technology Advancement (ITA).

Our distinguished faculty is composed of recognized experts in their fields, including 26 members of the National Academy of Engineering, and many junior faculty who are widely acclaimed for their work. Many faculty members are award-winning educators, and every faculty member, no matter how senior, teaches at least one undergraduate course each year.

UCLA Engineering is also committed deeply to public service. This includes translating research discoveries made here into applications and innovations that benefit the state and nation. It also includes partnerships in the community and with K-12 schools to inspire more young people to take an interest in science and engineering careers.

The UCLA Henry Samueli School of Engineering and Applied Science is seeking exceptional and dedicated students who share our desire to positively contribute to the engineering profession and society. I invite you to consider becoming a UCLA engineer.

Vijay K. Dhir
Dean
UCLA Henry Samueli School of Engineering and Applied Science
A Message from the Dean .................................. inside front cover
Henry Samueli School of Engineering and Applied Science ........... 3
Officers of Administration ........................................ 3
The Campus .......................................................... 3
The School ........................................................... 3
Endowed Chairs ...................................................... 4
The Engineering Profession ......................................... 4
Correspondence Directory .......................................... 6
General Information ................................................ 7
Facilities and Services ............................................. 7
Library Facilities .................................................... 7
Services .............................................................. 7
Continuing Education ............................................. 7
Career Services .................................................... 8
Arthur Ashe Student Health and Wellness Center .................... 8
Services for Students with Disabilities .............................. 8
Dashew Center for International Students and Scholars ........... 8
Fees and Financial Support ........................................ 8
Fees and Expenses ................................................ 8
Living Accommodations ........................................... 9
Financial Aid ........................................................ 9
Special Programs, Activities, and Awards ............................ 11
Center for Excellence in Engineering and Diversity ................ 11
Student Organizations ............................................ 12
Women in Engineering ............................................ 13
Student and Honorary Societies ................................... 13
Student Representation ............................................ 13
Prizes and Awards .................................................. 13

Departmental Scholar Program ..................................... 13
Official Publications .............................................. 13
Grading Policy ..................................................... 13
Grade Disputes ..................................................... 14
Nondiscrimination .................................................. 14
Harassment .......................................................... 14

Undergraduate Programs ........................................... 16
Admission .......................................................... 16
Requirements for B.S. Degrees .................................... 18
Honors ............................................................. 21

Graduate Programs ................................................ 22
Admission .......................................................... 23

Departments and Programs of the School ........................... 24
Bioengineering ....................................................... 24
Chemical and Biomolecular Engineering ............................ 35
Civil and Environmental Engineering ................................ 45
Computer Science ................................................ 56
Electrical Engineering ............................................. 73
Materials Science and Engineering .................................. 88
Mechanical and Aerospace Engineering ............................ 95
Master of Science in Engineering Online Program .................. 108
Schoolwide Programs, Courses, and Faculty ......................... 110

Externally Funded Research Centers and Institutes ................. 112
Curricula Charts ................................................... 114
Index .................................................................. 130

Calendars .............................................................. inside back cover

DISCLOSURE OF STUDENT RECORDS

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

UCLA, in accordance with federal and state laws and University policies, has des- ignated the following categories of personally identifiable information as “public information” that UCLA may release and publish without the student’s prior consent: name, address (local/mailing, permanent, and/or e-mail), telephone num- bers, major field of study, dates of attendance, enrollment status, grade level, number of course units in which enrolled, degrees and honors received, the most recent previous educational institution attended, participation in officially recog- nized activities (including intercollegiate athletics), and the name, weight, and height of participants on intercollegiate athletic teams.

As a matter of practice, UCLA does not publish student addresses or telephone numbers in the campus electronic directory unless released by the student. The term “public information” in this policy is synonymous with the term “directory information” in FERPA.

Students who do not wish certain items (i.e., name, local/mailing, permanent, and/or e-mail address, telephone numbers, major field of study, dates of attend- ance, number of course units in which enrolled, and degrees and honors re- ceived) of this “public information” released and published may so indicate through Ursa (http://www.ursa.ucla.edu). To restrict the release and publication of the additional items in the category of “public information,” complete the UCLA FERPA Restriction Request form available from the Registrar’s Office, 1113 Murphy Hall.

Student records that are the subject of federal and state laws and University pol- icies may be maintained in a variety of offices, including the Registrar’s Office, Of- fice of the Dean of Students, UCLA Career Center, Graduate Division, UCLA External Affairs Department, and the offices of a student’s College or school and major department. Students are referred to the online UCLA Campus Directory (http://www.directory.ucla.edu), which lists all the offices that may maintain stu- dent records, together with their campus address and telephone number. Students have the right to inspect their student records in any such office subject to the terms of federal and state laws and University policies. Inspection of student records maintained by the Registrar’s Office is by appointment only and must be arranged three working days in advance. Call (310) 825-1091, option 6, or inquire at the Registrar’s Office, 1113 Murphy Hall.

A copy of the federal and state laws, University policies, and the print UCLA Tele- phone Directory may be inspected in the office of the Information Practices Coordi- nator, 500 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of the Dean of Stu- dents, 1206 Murphy Hall.

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All announcements herein are subject to revision. Every effort has been made to ensure the accuracy of the information presented in the Announcement of the

UCLA Henry Samueli School of Engineering and Applied Science. However, all courses, course descriptions, instructor designations, curricular degree require- ments, and fees described herein are subject to change or deletion without notice. Further details on graduate programs are available in various Graduate Division publications, which are available online at http://grad.ucla.edu.

Cover: Artist’s rendering of the new UCLA Henry Samueli School of Engineering and Applied Science Engineering IV building now under construction. Ground- breaking took place on October 26, 2012.
Henry Samueili School of Engineering and Applied Science

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Tsou-Chin Lo, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Benjamin M. Wu, D.D.S., Ph.D., Professor and Chair, Bioengineering Department

The Campus
UCLA is a large urban university situated between the city and the sea at the foot of the Santa Monica Mountains. Less than six miles from the Pacific, it is bordered by Sunset and Wilshire Boulevards. As the city has grown physically and culturally, so has the campus, whose students and faculty mirror the cultural and racial diversity of today’s Los Angeles.

UCLA is one of the most widely respected and recognized universities in the world, and its impact on society can be felt into the far reaches of the globe. Students come from around the world to receive a UCLA education, and our alumni go on to become leaders in their fields, from elected officials to heads of international corporations.

UCLA is recognized as the West’s leading center for the arts, culture, and medical research. Each year, more than half a million people attend visual and performing arts programs on campus, while more than 300,000 patients from around the world come to the Ronald Reagan UCLA Medical Center for treatment. The university’s 419-acre campus houses the College of Letters and Science and 11 professional schools. There are more than 41,340 students enrolled in 128 undergraduate and 197 graduate degree programs. Nearly one in every 140 Californians holds a UCLA degree.

UCLA is rated one of the best public research universities in the U.S. and among a handful of top U.S. research universities, public and private. The chief executive of the University is Chancellor Gene D. Block. He oversees all aspects of the University’s three-part mission of education, research, and service.

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

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

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) strives to revolutionize development of consumer electronics by engineering materials that optimize energy efficiency, size, and power output on the small scale. The Focus Center on Function Accelerated nanoMaterial Engineering (FAME) aims to revolutionize semiconductor technologies by developing new nanoscale materials and structures that take advantage of properties unavailable at larger scales. The Western Institute of Nanoelectronics (WIN), among the world’s largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically needed innovations in semiconductor technology. The Center for Molecularly Engineered Energy Materials (MEEM) focuses on the creation and production of nanoscale materials for use in converting solar energy into electricity and electrical energy storage, and capturing and separating greenhouse gases. The Center for Domain-Specific Computing (CDSIC) is developing high-performance, energy efficient, customizable computing that could revolutionize the way computers are used in healthcare and other important applications. The Smart Grid Energy Research Center (SMERC) conducts research, creates innovations, and demonstrates advanced wireless/communications, Internet, and sense-and-control technologies to enable the development of the next generation of the electric utility grid. The Wireless Health Institute (WHI) is a community of UCLA experts and innovators from a variety of disciplines dedicated to improving healthcare delivery through the development and application of wireless network-enabled technologies integrated with current and next-generation medical enterprise computing. The Named Data Networking (NDN) Project is investigating the future of the Internet’s architecture, capitalizing on its strengths and addressing weaknesses, to accommodate emerging patterns of communication. Finally, the California NanoSystems Institute (CNSI)—a joint endeavor with UC Santa Barbara—develops the information, biomedical, and manufacturing technologies of the twenty-first century.

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

And the school has established the Institute for Technology Advancement (ITA), an off-campus institute dedicated to the effective transition of high-impact innovative research from UCLA to product development and commercialization. ITA nurtures and incubates breakthrough ideas to create new industrial products, as well as provides a learning platform for faculty members and students to engage in transitional technology research.

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

Master of Science and Ph.D. degrees are offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Manufacturing Engineering (M.S. only), Materials Science and Engineering, and Mechanical Engineering. A schoolwide online Master of Science in Engineering degree program is also offered. 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 22. A one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science.

**Endowed Chairs**

Endowed professorships or chairs, funded by gifts from individuals or corporations, support the research and educational activities of distinguished members of the faculty. The following endowed chairs have been established in the Henry Samueli School of Engineering and Applied Science.

L.M.K. Boelter Chair in Engineering
Traugott and Dorothea Frederking Endowed Chair in Cryogenics
Norman E. Friedmann Chair in Knowledge Sciences
Leonard Kleinrock Chair in Computer Science
Evelyn Knight Chair in Engineering
Levi James Knight, Jr., Chair in Engineering
Richard G. Newman AECOM Endowed Chair in Civil 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 Foundation 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
Charles P. Reames Endowed Chair in Electrical Engineering
Edward K. and Linda L. Rice Endowed Chair in Materials Science
Ben Rich Lockheed Martin Chair in Aeronautics
Rockwell Collins Chair in Engineering
William Frederick Seyer Chair in Materials Electrochemistry
Ronald and Valerie Sugar Endowed Chair in Engineering
Symantec Chair in Computer Science
Carol and Lawrence E. Tannas, Jr., Endowed Chair in Engineering
William D. Van Vorst Chair in Chemical Engineering Education
Wintek Endowed Chair in Electrical Engineering

**The Engineering Profession**

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

**Aerospace Engineering**

Aerospace engineers conceive, design, develop, test, and supervise the construction of aerospace vehicle systems such as commercial and military aircraft, helicopters and other types of rotorcraft, and space vehicles and satellites, including launch systems. They are employed by aerospace companies, airplane 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 prepares students for careers at the forefront of aerospace technology. The Ph.D. degree 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 engineering, medicine, and basic sciences, bioengineering has emerged and established itself internationally as an engineering discipline in its own right. Such an interdisciplinary education is necessary to develop a quantitative engineering approach to tackle complex medical and biological problems, as well as to invent and improve the ever-evolving experimental and computational tools that are required in this engineering approach. 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 the basic sciences. Rigorously trained bioengineers are in demand in research institutions, academia, and industry. Their careers may follow a bioengineering concentration, but the ability of bioengineers to cut across traditional boundaries will facilitate their innovation in new areas.

**Chemical and Biomolecular Engineering**

Chemical and biomolecular engineers use their knowledge of mathematics, physics, chemistry, biology, and engineering to meet the needs of our technological society. They design, research, develop, operate, and manage within the biochemical and chemical industries and are leaders in the fields of energy and the environment, nanotechnology, systems engineering, biotechnology and biomolecular engineering, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, biotechnology, biofuel, food, aerospace, automotive, water treatment, and semiconductor industries. Architectural, engineering, and construction firms employ chemical engineers for equipment and process design. It is also their mission to develop the clean and environmentally friendly technologies of the future.

Major areas of fundamental interest within chemical engineering are

1. **Applied chemical kinetics**, which involves the design of chemical and biochemical reaction processes and reactors,
2. **Transport phenomena**, which involves the exchange of momentum, heat, and mass in physical and biological systems 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 physical, chemical, and biological processes, and
4. Process design and synthesis, which provide the overall framework and computing technology 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 other industries for assignments based on their engineering background. Graduates are also qualified for positions outside engineering where their broad engineering education is a valuable asset.

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

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

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

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

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

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

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

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

Coursework, independent studies, and research are offered in the manufacturing processes area, leading to an M.S. degree. This includes computer-aided design and computer-aided manufacturing, robotics, metal forming and metal cutting analysis, non-destructive 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 mechanics, 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.

Mechanical engineers apply their knowledge to a wealth of systems, products, and processes, including energy generation, utilization and conservation, power and propulsion systems (power plants, engines), and commercial products found in the automotive, aerospace, chemical, or electronics 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. The Ph.D. degree provides a strong background for employment by government laboratories, industrial research laboratories, and academia.
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5121 Engineering V
http://www.bioeng.ucla.edu

Chemical and Biomolecular Engineering Department
5531 Boelter Hall
http://www.chemeng.ucla.edu

Civil and Environmental Engineering Department
5731 Boelter Hall
http://www.cee.ucla.edu

Computer Science Department
4732 Boelter Hall
http://cs.ucla.edu

Electrical Engineering Department
58-121 Engineering IV
http://www.ee.ucla.edu

Materials Science and Engineering Department
3111 Engineering V
http://www.seas.ucla.edu/ms/

Mechanical and Aerospace Engineering Department
48-121 Engineering IV
http://www.mae.ucla.edu

Continuing Education in Engineering
542 UNEX
http://www.uclaextension.edu

Engineering and Science Career Services
UCLA Career Center
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http://career.ucla.edu

Master of Science in Engineering Online Program
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http://msol.ucla.edu

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Undergraduate Admissions and Relations with Schools
1147 Murphy Hall
http://www.admissions.ucla.edu

Graduate Diversity, Inclusion and Admissions Office
1248 Murphy Hall
http://www.grad.ucla.edu/gasaa/admissions/applicat.htm

Financial Aid Office
A123J Murphy Hall
http://www.fao.ucla.edu

Registrar’s Office
1105 Murphy Hall
http://www.registrar.ucla.edu

Dashew Center for International Students and Scholars
106 Bradley Hall
http://www.internationalcenter.ucla.edu

Summer Sessions
1147 Murphy Hall
http://www.summer.ucla.edu

University of California
Office of the President–Admissions
http://admission.universityofcalifornia.edu
General Information

Facilities and Services

Teaching and research facilities at HSSEAS are in Boelter Hall, Engineering I, Engineering IV, and Engineering V, located in the southern part of the UCLA campus. Boelter Hall houses classrooms and laboratories for undergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoasa.ucla.edu), the SEASNet computer facility (http://www.seas.ucla.edu/seasnet/), and offices of faculty and administration. The SEL/Engineering and Mathematical Sciences Library is also in Boelter Hall. The Shop Services Center and the Student and Faculty Shop are in the Engineering I building. The California NanoSystems Institute (CNSI) building hosts additional HSSEAS collaborative research activities.

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 11 million volumes, and nearly 112,000 serial titles are received regularly. Nearly 53,000 serials and databases are electronically available through the UCLA Library Catalog, which is linked to the library’s homepage at http://www.library.ucla.edu.

Science and Engineering Library

The SEL/Engineering and Mathematical Sciences Collection in Boelter Hall houses the engineering, mathematics, statistics, astronomy, chemistry, physics, and atmospheric and oceanic sciences collections, as well as most librarian and staff offices. The library also provides laptop checkout, three group study rooms, a presentation rehearsal studio, and a research commons for collaborative projects. Librarians provide reference assistance from 10 a.m. to 12 noon and 1 to 5 p.m. Monday through Friday in person and by e-mail. Faculty, students, and staff can e-mail questions to SEL librarians at sel-ref@library.ucla.edu.

The SEL collection contains more than half a million print volumes, subscriptions to nearly 5,000 current serials in print or electronic formats, and over 4 million technical reports. In addition to e-journals, the library provides Web access to article databases covering each discipline and well over ten thousand e-books.

The SEL website, located at http://www.library.ucla.edu/libraries/stl/, highlights other library services including course reserves, laptop lending, interlibrary loan, document delivery, and other services, the SEL blog, and others useful engineering Web resources. Librarians are available for consultations and to provide course-related instruction.

Services

Instructional Computer Facility

HSSEAS maintains a network of over 130 enterprise servers that provide a wide array of critical services for School of Engineering students, faculty, and staff. Network Appliance NFS servers supply reliable storage for user's personal data and e-mail, and offer nearly instant recovery of deleted files through regular snapshots.

More than 100 Unix servers, including 25 virtual machines, provide administrative and instructional support to ensure smooth operation of approximately 700 Linux and Windows workstations. The Unix servers provide backend services such as DNS, authentication, virtualization, software licensing, web servers, interactive log-in, database, e-mail, class applications, and security monitoring.

Twelve Windows servers make up the backbone for all instructional computing labs and allow students to work remotely with computational and resource-intensive applications. There are three computer labs and two instructional computer labs with 200 Windows workstations.

A high-speed network that links the entire infrastructure ensures a latency-free operation for users from UCLA and around the world. It consists of dual fiber uplinks to a Cisco core router that feeds and routes 20 networks over 150 switches, and 50 Cisco wireless access points. The network serves over 8,000 users across four buildings.

For backup and disaster recovery, large capacity LTO tapes are used to back up servers and selected user workstations regularly, and incremental backups are done to online disk storage. The LTO tapes are sent to off-site storage for disaster recovery.

The servers are protected by two UPS units for short-term power outages, and campus emergency power keeps critical equipment running during extended downtime.

Students and faculty have access to retail Microsoft software through the Microsoft Developer Network Academic Alliance (MSDN-AAA) program, and MathType software through an HSSEAS download service, at no charge. Faculty and staff have access to Adobe professional and Microsoft Office (MCCA) software at no charge through the HSSEAS download service. Abaqus, Autodesk, and Dreamspark programs offer additional software at no charge to all UCLA students. Ansys offers a student version of its software for a very low fee.

UCLAS Office of Information Technology (OIT) operates high-performance computer clusters that offer cluster hosting services to campus researchers in a way that effectively manages the limited high-end data center space on campus. They offer help to researchers who need assistance in numerically intensive computing by speeding up long-running serial or parallel programs or by parallelizing existing serial code. A UCLA Grid Portal and other high-performance computing resources are also available.

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 and Technology

Varaz Shahmirian, Ph.D., Director
Rachel Khoshbin, Ph.D., Program Director

The UCLA Extension (UNEX) Department of Engineering and Technology (540 UNE, 10995 Le Conte Avenue) provides one of the nation’s largest selections of continuing engineering education programs. A short course program of 150 annual offerings draws participants from around the world for two- to four-day intensive programs. Many of these short courses are also offered on-site at companies and government agencies; see https://www.uclaextension.edu/shortcourses/. The acclaimed Technical Management Program holds its 86th offering in September 2013 and
The Information Systems program offers over 100 courses annually in systems analysis, applications programming, database management, Linux/Unix, operating systems, and web technology.

The engineering program offers over 200 courses annually, including 10 certificate programs in astronautical engineering, construction management, communication systems, digital signal processing, manufacturing engineering, project management, contract management, government cost estimating and pricing, supply chain management, and recycling and solid waste management. In addition, the department offers EIT and PE review courses in mechanical, civil, and chemical engineering. Most engineering and technical management courses are offered evenings on the UCLA campus, or are available online. See https://www.uclaextension.edu/eistm/.

Career Services

The UCLA Career Center assists HSSEAS undergraduate and graduate students and alunmi in exploring career possibilities, preparing for graduate and professional school, obtaining employment and internship leads, and developing skills for conducting a successful job search. Several sections of the Education 150 course Strategic Career Decision-Making are offered through the Career Center each quarter. 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 undergraduate and graduate students with opportunities to meet one-on-one with employers seeking entry-level job candidates and offers 24-hour access to thousands of current full-time, part-time, seasonal, and internship positions. The annual engineering and technical fairs are held in Fall and Winter quarters, and HSSEAS students are also welcomed at all Career Center-sponsored job fairs.

The Career Center staff also provides consultation services to HSSEAS student organizations. 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 and for same-day counseling sessions. For more information call (310) 206-1915 or see http://career.ucla.edu.

Arthur Ashe Student Health and Wellness Center

The Arthur Ashe Student Health and Wellness Center is a full-service medical clinic available to all registered UCLA students. Its clinical staff of physicians, nurse practitioners, and nurses is board-certified. It offers primary care, specialty clinics, and physical and occupational therapy. The center has its own pharmacy, optometry, radiology, and laboratory. Visit, core laboratory test, X-ray fees, and preventive immunizations are all pre-paid for students with the University of California Student Health Insurance Plan (UCSHIP). Students with UCHSIP pay lower co-pays for prescriptions filled at the Ashe Center pharmacy. UCHSIP students must begin all non-emergency medical care at the Ashe Center. All fees incurred at the Ashe Center are billed directly to students’ BruinBill accounts.

If a student withdraws, is dismissed, has registration fees cancelled, or takes a leave of absence during a term, he or she continues to be eligible for health services for the remainder of the term at full cost. If a student with UCHSIP withdraws with a less than 100% refund, UCHSIP continues through the remainder of the term.

The cost of services received outside the Ashe Center is each student’s financial responsibility. Students who waive UCHSIP need to ensure that they are enrolled in a plan qualified to cover expenses incurred outside of the Ashe Center, and are responsible for knowing the benefits of and local providers for their medical plan.

For emergency care when the Ashe Center is closed, students may call nurse line telephone triage services at (866) 704-9660, or obtain treatment at the UCLA Medical Center Emergency Room or the nearest emergency room on a fee-for-service basis. It is the student’s responsibility to have insurance billed. A student with UCHSIP must have follow-up visits, after emergencies, in the Ashe Center. If care cannot be provided in the Ashe Center, the Ashe Center clinician will give the student a written referral to a network provider.

The Ashe Center website processes students’ proof of immunity to Hepatitis B prior to enrollment. Information about this requirement is available on the Ashe website; for questions, send e-mail to shshepb@ashe.ucla.edu.

Office hours during the academic year are weekdays 8 a.m. to 6:30 p.m. except Friday, when service begins at 9 a.m. Located at 221 Westwood Plaza (next to John Wooden Center), (310) 825-4073; see http://www.studenthealth.ucla.edu.

Services for Students with Disabilities

The Office for Students with Disabilities (OSD) is the only campus entity authorized to determine a student’s eligibility for disability-related accommodations and services. Academic support services are determined for each regularly enrolled student with documented permanent or temporary disabilities based on specific disability-based requirements. OSD policies and practices comply with all applicable federal and state laws, including Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (ADA) of 1990, and are consistent with University policy.

Services include campus orientation and accessibility, note takers, reader service, sign language interpreters, Learning Disability Program, registration assistance, test-taking facilitation, special parking assistance, real-time captioning, assistive listening devices, on-campus transportation, adaptive equipment, support groups and workshops, tutorial referral, special materials, housing appeals, referral to UCLAs Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations. There is no fee for any of these services. All contacts and assistance are handled confidentially. Located at A255 Murphy Hall, voice (310) 825-1501, TTY (310) 206-6083; see http://www.osd.ucla.edu.

Dashew Center for International Students and Scholars

The Dashew Center for International Students and Scholars assists international students with questions about immigration, employment, government regulations, financial aid, academic and administrative procedures, cultural adjustment, and personal matters. The center provides visa assistance for faculty researchers, and postdoctoral scholars. It also offers programming to meet the needs of the campus multicultural population. Located at 106 Bradley Hall; see http://www.internationalcenter.ucla.edu.

Fees and Financial Support

Fees and Expenses

Annual UCLA student fees shown for 2013-14 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 stu-
students) pay nonresident supplemental tuition. See the UCLA General Catalog appendix or the UCLA Registrar’s website residence section at http://www.registrar.ucla.edu/residence/index.htm 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 listed, students should be prepared to pay living expenses for the academic period.

Living Accommodations

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

The Community Housing Office, 360 De Neve Drive, Box 951495, Los Angeles, CA 90095-1495, (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 UCLA Housing Services, 360 De Neve Drive, Box 951381, Los Angeles, CA 90095-1381, (310) 206-7011; see http://www.housing.ucla.edu. Newly admitted students are sent UCLA Housing, which describes costs, locations, and eligibility for both private and UCLA-sponsored housing.

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 2014-15 academic year is March 2, 2014. 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).

College Housing Office, 360 De Neve Drive, Los Angeles, CA 90024-1429.

In 2012-13, HSSEAS awarded more than 95 undergraduate scholarship awards totaling more than $370,000. The majority of these scholarships are publicized in the Fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see http://seasoasa.ucla.edu/student-opportunities/scholarships-for-undergraduates.

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

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.

HSSEAS Scholarships are awarded to entering and continuing undergraduate students based on criteria including financial need, academic excellence, community service, extracurricular activities, and research achievement. The school works with alumni, industry, and individual donors to establish scholarships to benefit engineering students. In 2012-13, HSSEAS awarded more than 95 undergraduate scholarship awards totaling more than $370,000. The majority of these scholarships are publicized in the Fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see http://seasoasa.ucla.edu/student-opportunities/scholarships-for-undergraduates.

Grants

Cal Grants A and B are awarded by the California Student Aid Commission to entering residents.

For undergraduate students choosing UC SHIP with the dental option, the annual fee is $1,800.70.

**Beginning with the first academic term following advancement to doctoral candidacy, nonresident supplemental tuition for graduate students is reduced by 100% for a maximum of three years including nonregistered time periods.**

### 2013-14 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES

<table>
<thead>
<tr>
<th>Fees</th>
<th>Resident</th>
<th>Nonresident</th>
<th>Resident</th>
<th>Nonresident</th>
<th>Resident</th>
<th>Nonresident</th>
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<tr>
<td>Student Services Fee</td>
<td>$ 972.00</td>
<td>$ 972.00</td>
<td>$ 972.00</td>
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<td>PLEDGE Fee</td>
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<td>Graduate Students Association Fee</td>
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<td>Graduate Writing Center Fee</td>
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<td>Wooden Center Fee</td>
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<tr>
<td>Student Programs, Activities, and Resources Complex Fee</td>
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<td>Student Health Insurance Plan (UCSHIP)<strong>for undergraduates only, without dental option</strong></td>
<td>1,530.46</td>
<td>1,530.46</td>
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<td>Course Materials and Services Fee</td>
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<td>Nonresident Supplemental Tuition</td>
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<td>$ 15,288.38</td>
<td>$ 30,410.38</td>
<td>$ 15,308.38</td>
<td>$ 30,410.38</td>
</tr>
</tbody>
</table>
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 tuition and fees.

**Federal Pell Grants** are federal aid awards designed to provide financial assistance to U.S. citizens or eligible noncitizen undergraduates in exceptional need of funds to attend post-high school educational institutions. Students who file a FAFSA are automatically considered for a Pell Grant.

Detailed information on other grants for students with demonstrated need is available from the Financial Aid Office.

**Federal Family Education Loan Program**

**Federal loans** are available to undergraduate or graduate students who are U.S. citizens or eligible noncitizens and who carry at least a half-time academic workload. Information on loan programs is available from the Financial Aid Office, 129J Murphy Hall, or on the web at http://www.fao.ucla.edu.

All loan recipients must complete an exit interview with Student Loan Services and Collections before leaving UCLA for any reason. This interview helps students understand their loan agreement and plan for loan repayment. Failure to complete an exit interview results in a hold being placed on all university services and records. In addition, if the campus-based loans become delinquent following separation from UCLA, all university services and records will be withheld. For further information concerning loan repayment, visit Student Loan Services and Collections, A227 Murphy Hall, (310) 825-9864; see http://www.loans.ucla.edu.

**Work-Study Programs**

Under the **Federal Work-Study**, the federal government pays a portion of the student's wage and the employer pays 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 FAFSA is required.

Students must be enrolled at least half-time (6 units for undergraduates, 4 for graduate students) and not be appointed at more than 50 percent time while employed at UCLA. Students not meeting these requirements are subject to Social Security and Medicare taxation.

**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 up to a total of $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.

**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.
2. Employment as a teaching assistant.
3. Employment as a graduate student researcher.

Fellowships usually provide stipends competitive with those of other major universities, plus tuition and nonresident supplemental tuition (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.

**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. Full-time employment in summer and interim breaks is possible, depending on the availability of research funds from contracts or grants.

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

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2013-14 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 (FAFSA). Continuing graduate students should contact the Financial Aid Office in December 2013 for information on 2014-15 application procedures.

International graduate students are not eligible for need-based University financial aid or for long-term student loans.

**School of Engineering Fellowships**

Fellowship packages offered by HSSEAS may include fellowship contributions from the following sources:

- AT&T Fellowships. Supports doctoral study in electrical engineering; must be U.S. citizen or permanent resident; optional summer research at AT&T
- Atlantic Richfield Company (ARCO) Fellowship. Department of Chemical and Biomolecular Engineering; supports study in chemical engineering
- William and Mary Boedle Fellowship. Department of Chemical and Biomolecular Engineering; supports study in chemical engineering
- John J. and Clara C. Boeotter Fellowship. Supports study in engineering
- Broadcom Fellowship. Electrical Engineering Department; supports doctoral students who have passed the preliminary examination and who are doing research which explores new possibilities in state-of-the-art 22-nm CMOS technology
- Leon and Alyne Camp Fellowship. Department of Mechanical and Aerospace Engineering; supports study in engineering; must be U.S. citizen
- Deutsch Company Fellowship. Supports engineering research on problems that aid small business in Southern California
- IBM Doctoral Fellowship. Supports doctoral study in computer science
- Intel Fellowship. Department of Computer Science; supports doctoral study in selected areas of computer science
- Intel Fellowship. Department of Mechanical and Aerospace Engineering; supports doctoral students
- Les Knesel Scholarship Fund. Department of Materials Science and Engineering; supports master's or doctoral students in ceramic engineering
- Guru Krupe Foundation Fellowship. Department of Electrical Engineering; supports graduate students who received their undergraduate degrees in electrical engineering from top Indian Institutes of Technology (IIT)
- T.H. Lin Graduate Fellowship. Department of Civil and Environmental Engineering; supports study in the area of structures
Living Spring Fellowship. Department of Electrical Engineering; supports graduate students with electrical engineering degrees from National Taiwan University, National Tsing Hua University (Taiwan) or National Chiao Tung University (Taiwan)

Microsoft Fellowship. Supports doctoral study in computer science

National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) Fellowships. Supports study in engineering and science to highly qualified individuals from communities where human capital is virtually untapped

Qualcomm Innovation Fellowship. Supports doctoral students across a broad range of technical research areas based on Qualcomm core values of innovation, execution, and teamwork

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

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

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

UCLA HSSEAS Electrical Engineering Fellowship funded by Qualcomm Technologies, Inc. Department of Electrical Engineering; supports doctoral students performing research in the broad areas of interests to Qualcomm within the wireless paradigm

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. In addition, the Graduate Division offers other fellowship packages including the Dissertation Year, the Eugene V. Cota-Robles, and Graduate Opportunity Fellowships.

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 precollege students in science, engineering, mathematics, and technology curricula, and focuses on engineering and computer science at the undergraduate and graduate levels.

Precollege Outreach Programs

Science and Mathematics Achievement and Research Training for Students (SMARTS). A six-week commuter summer program, SMARTS provides a diverse group of up to 50 10th and 11th graders with rigorous inquiry-based engineering, mathematics, and science enrichment. Students 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.

Summer Math and Science Honors Academy (SMASH). A rigorous and innovative education program, SMASH increases opportunities for educationally and financially disadvantaged urban school students to excel in the fields of science, technology, engineering, and math (STEM) at the college level for five weeks each summer. SMASH scholars also receive year-round academic support including SAT preparation, college counseling, financial aid workshops, and other activities to ensure continued academic success. Thirty new SMASH scholars are selected each year to attend the residential program each of three summers (after their 9th, 10th, and 11th grade years). Approximately 90 students are expected to be participating in SMASH by summer 2014.

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 917 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 four schools in the Inglewood Unified School District.

Undergraduate Programs

CEED currently supports some 260 underrepresented and educationally disadvantaged engineering students. Components of the undergraduate program include

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

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

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 the National Science Foundation (NSF). 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.

Research Intensive Series in Engineering for Underrepresented Populations (RISE-UP). During the summer of 2005, UCLA CEED began its Research Intensive Series in Engineering for Underrepresented Populations (RISE-UP). The purpose of this program is to keep engineering and computing students, particularly from underrepresented groups, interested in the fun of learning through a process in which faculty participate. The ultimate goal of this program is to encourage these young scholars to go on to graduate school and possibly the professoriate.

Academic Advising and Counseling. A CEED counselor assists in the selection of course combinations, professors, and course loads and meets 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 complex with a study area open 24 hours a day, the Student Study Center also houses a computer room and is used for tutoring, presentations, and engineering student organizations.

Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS): The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) brings together critical expertise in physics, chemistry, materials science, and engineering to enable rapid advancement and application of multiferroic technologies to next-generation electromagnetic (EM) devices. Its goal is to create a synergistic environment that fosters fundamental studies on magnetism control through application of an electric field and provides a pathway to commercial endeavors. Its unique needs include diverse participant characteristics that encompass how we think, how we do things, and our humanity—including but not limited to age, color, culture, disability, diversity of thought, ethnicity, gender, geographic and national origin, language, life experience, perspective, race, religion, sexual identity, socioeconomic status, and technical expertise—aimed to increase creativity and innovation. The center’s workforce is composed of researchers who span a wide range of disciplines from chemical to mechanical engineering, and an educational spectrum from K-12 and undergraduate students to post-doctoral scholars, including those who work with industries and national laboratories focused on nanoscale multiferroics.

TANMS’ vision is to move from diversity and inclusion advocate to active leader in the ERC community, and provide an educational pathway from cradle to career for the nation’s best and brightest, fully representative and inclusive of the talents of every community. TANMS recognizes diversity as a national imperative to take specific actions by its leadership to source and include a complete talent pool, especially those critically underrepresented populations, and all its population segments and characteristics, in TANMS’ academic leadership, technical workforce, and efforts to develop the next generation of engineers, scientists, and entrepreneurs in multiferroics systems.

TANMS is a multi-university partnership between lead institution UCLA and partners California State University Northridge, Cornell University, UC Berkeley, and Switzerland’s Edgenossische Technische Hochschule. CEED directs the TANMS program component, supports undergraduates placed in research laboratories, and coordinates recruitment of undergraduates from other universities. CEED brings teacher-student teams to UCLA to conduct summer research and gain exposure to entrepreneurship.

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 scholar-ships. Information may be obtained from the CEED director.

Student Organizations
UCLA CEED supports student chapters of three engineering organizations: the American Indian Science and Engineering Society (AISES), the National Society of Black Engineers (NSBE), and the Society of Latino Engineers and Scientists (SOLES), the UCLA chapter of the Society of Hispanic Professional Engineers (SHPE). These organizations are vital elements of the program.

American Indian Science and Engineering Society
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 various activities sponsored by NSBE, students develop leadership and interpersonal skills while enjoying the college experience. UCLA NSBE was recently named national chapter of the year for small chapters by the national organization. See http://sites.google.com/site/uclansbe/.

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

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

Women in Engineering

Women make up about 21 percent of the HSSEAS undergraduate and 20 percent of the graduate enrollment. Today's opportunities for women in engineering are excellent, as both employers and educators try to change the image of engineering as a “males only” field. Women engineers are in great demand in all fields of engineering.

Society of Women Engineers

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

Student and Honorary Societies

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

- ACM Association for Computing Machinery
- AIAA American Institute of Aeronautics and Astronautics
- AIChE American Institute of Chemical Engineers
- AISES American Indian Science and Engineering Society
- ASCE American Society of Civil Engineers
- ASME American Society of Mechanical Engineers
- BEAM Building Engineers and Mentors
- BMES Biomedical Engineering Society
- — Bruin Amateur Radio Club
- CalGeo California Geoprofessionals Association
- Chi Epsilon Civil Engineering Honor Society
- CSGSC Computer Science Graduate Student Committee
- EGSA Engineering Graduate Students Association
- ESUC Engineering Society, University of California. Umbrella organization for all engineering and technical societies at UCLA
- Eta Kappa Nu Electrical engineering honor society
- EWB Engineers Without Borders
- IEEE Institute of Electrical and Electronic Engineers
- ISPE International Society for Pharmaceutical Engineering
- ITE Institute of Transportation Engineers
- LUG Linux Users Group
- MRS Materials Research Society
- NSBE National Society of Black Engineers
- Phi Sigma Rho Engineering social sorority
- San Diego Engineer Students Association: 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, outstanding students are recognized for their academic achievement and exemplary record of contributions to the school. Recipients are acknowledged in the HSSEAS annual commencement program as well as by campuswide announcement.瓦

- The Russell R. O’Neil 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, the school, and to the advancement of the undergraduate engineering program, through service and participation in extracurricular activities.

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

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

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

Departmental Scholar Program

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

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

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

Official Publications

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

For rules and regulations on graduate study, see http://grad.ucla.edu.
Grading Policy
Instructors should announce their complete grading policy in writing at the beginning of the term, along with the syllabus and other course information, and make that policy available on the course website. Once the policy is announced, it should be applied consistently for the entire term.

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), physical or mental disability, medical condition (cancer-related or genetic characteristics), ancestry, marital status, age, sexual orientation, citizenship, or service in the uniformed services (including membership, performance of service, application for service, or obligation for service in the uniformed services). 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) 206-6985.

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 the ADA and 504 Compliance Coordinator, A239 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 825-1514, TTY (310) 206-3349. See http://www.ucla.edu.

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.ucla.edu/ucpolicies/aos/toc.html) for further information and procedures.

Harassment
Sexual Harassment
The University of California is committed to creating and maintaining a community where all persons who participate in University programs and activities can work and learn together in an atmosphere free from all forms of harassment, exploitation, or intimidation. Every member of the University community should be aware that the University is strongly opposed to sexual harassment and that such behavior is prohibited both by law and by University policy. The University will respond promptly and effectively to reports of sexual harassment and will take appropriate action to prevent, correct and, if necessary, discipline behavior that violates this policy. See http://www.sexualharassment.ucla.edu.

Definitions
Sexual, racial, and other forms of harassment, are defined as follows:

- Harassment is defined as conduct that is so severe and/or pervasive, and objectively offensive, and that so substantially impairs a person’s access to University programs or activities that the person is effectively denied equal access to the University’s resources and opportunities on the basis of the individual’s race, color, national or ethnic origin, citizenship, sex, religion, age, sexual orientation, gender identity, pregnancy, marital status, ancestry, service in the uniformed services, physical or mental disability, medical condition, or perceived membership in any of these classifications.

- When employed by the University of California, and acting within the course and scope of that employment, students are subject to the University of California Policy on Sexual Harassment. Otherwise, the above paragraph is the applicable standard for harassment by students.

Complaint Resolution
Experience has demonstrated that many complaints of sexual harassment can be effectively resolved through informal interven-
Other Forms of Harassment

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

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

Similarly, harassing conduct, including symbolic expression, which also involves conduct resulting in damage to or destruction of any property of the University or property of others while on University premises may subject a student violator to University discipline under the provisions of Section 102.04 of the Policies. Further, under specific circumstances described in Section 102.11 of the Policies, 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, 101 Murphy Hall, or in any of the Harassment Information Centers listed below:

1. Counseling and Psychological Services, 221 Wooden Center West, (310) 825-0768, http://www.counseling.ucla.edu
2. Dashew Center for International Students and Scholars, 106 Bradley Hall, (310) 825-1681, http://www.internationalcenter.ucla.edu

Complaint Resolution

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

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

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

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

The Henry Samueli School of Engineering and Applied Science (HSSEAS) offers nine four-year curricula listed below (see the departmental listings for complete descriptions of the programs), in addition to undergraduate minors in Bioinformatics and in Environmental Engineering:

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

The aerospace engineering, bioengineering, chemical engineering, civil engineering, computer science and engineering, electrical engineering, materials engineering, and mechanical engineering programs are accredited by the Engineering Accreditation Commission (EAC) of ABET, http://www.abet.org. The computer science and computer science and engineering curricula are accredited by the Computing Accreditation Commission of ABET, http://www.abet.org.

Admission

Applicants to HSSEAS must satisfy the general admission requirements of the University. See the Office of Admissions and Relations with Schools (OAR) website at http://www.admissions.ucla.edu for details. Applicants must apply directly to HSSEAS by selecting one of the majors within the school or the undeclared engineering option. In the selection process many elements are considered, including grades, test scores, and academic preparation.

Students applying as freshmen or transfers must submit their applications during the November 1 through 30 filing period. In addition, it is essential that official test scores be received no later than the date in January when the December test scores are normally reported.

Applicants must submit scores from an approved core test of mathematics, language arts, and writing. This requirement may be satisfied by taking either (1) the ACT Assessment plus Writing Tests or (2) the SAT Reasoning Test. Applicants to the school are strongly encouraged to also take the following SAT Subject Tests: Mathematics Level 2 and a laboratory science test (Biology E/M, Chemistry, or Physics) that is closely related to the intended major.

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

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

Admission as a Freshman

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

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

Credit for Advanced Placement Examinations

Students may fulfill part of the school requirements with credit allowed at the time of admission for College Board Advanced Placement (AP) Examinations with scores of 3, 4, or 5. Students with AP Examination credit may exceed the 213-unit maximum by the amount of this credit. AP Examination credit for freshmen entering Fall Quarter 2013 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 Examination 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 3.3 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 Computer Science and Engineering majors and the electrical engineering and computer engineering options of the Electrical Engineering major require only one term of chemistry
4. Computer programming, including either Java, C, or C++. Applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors must take C++
5. Biology, including one year of biology only for applicants to the Bioengineering major
6. English composition courses, including one course equivalent to UCLA’s English Composition 3 and a second UC-transferable English composition course

Transfer applicants may complete courses in addition to those above that satisfy degree requirements. Engineering and computer science courses appropriate for each major may be found at http://www.assist.org.
Henry Samueli School of Engineering and Applied Science
Advanced Placement Examination Credit

All units and course equivalents to AP Examinations are lower division. If an AP Examination 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 Examination</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>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Science (A Test)</td>
<td>3, 4, or 5</td>
<td>2 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Course</td>
<td>Units</td>
<td>Description</td>
<td>Application</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------</td>
<td>--------------------------------------------------</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>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Japanese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Latin</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td>May be applied toward Mathematics 31A</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units</td>
<td>4 units may be applied toward Mathematics 31A</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units</td>
<td>Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td>3</td>
<td>8 units maximum for all tests</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Mechanics)</td>
<td>3</td>
<td>4 units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Physics 1A)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Electricity and Magnetism)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics 33B. Differential Equations (4 units)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics 1A. Physics for Scientists and Engineers: Mechanics (5 units)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Physics 1B. Physics for Scientists and Engineers: Oscillations, Waves, Electric and Magnetic Fields (5 units)</td>
<td></td>
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<tr>
<td>Physics 1C. Physics for Scientists and Engineers: Electrodynamics, Optics, and Special Relativity (5 units)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Physics 4AL. Physics Laboratory for Scientists and Engineers: Mechanics (2 units)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Physics 4BL. Physics Laboratory for Scientists and Engineers: Electricity and Magnetism (2 units)</td>
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</tr>
</tbody>
</table>

**Lower Division Courses in Other Departments**

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

**Requirements for B.S. Degrees**

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

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

**University Requirements**

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

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

Unit Requirement
The minimum units allowed for HSSEAS students is between 183 and 190, depending on the program. The maximum allowed is 213 units.
After 213 quarter units, enrollment may not normally be continued in the school without special permission from the associate dean. This regulation does not apply to Departmental Scholars.

Scholarship Requirement
In addition to the University requirement of at least a C (2.0) grade-point average in all courses taken at any University of California campus, students must achieve at least a 2.0 grade-point average in all upper division University courses offered in satisfaction of the subject and elective requirements of the curriculum. A 2.0 minimum grade-point average in upper division mathematics, upper division core courses, and the major field is also required for graduation. Grade point averages are not rounded up.

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

Writing Requirement
Students must complete the University’s Entry-Level Writing or English as a Second Language (ESL) requirement prior to completing the school writing requirement.

Students admitted to the school are required to complete a two-term writing requirement—Writing I and engineering writing. Both courses must be taken for letter grades, and students must receive grades of C or better (C– grades are not acceptable) by the end of the second year of enrollment.
The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement Examinations in English or a combination of a score of 720 or higher on the SAT Reasoning Test Writing Section and superior performance on the English Composition 3 Proficiency Examination.

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

Engineering Writing

The engineering writing requirement is satisfied by selecting one approved engineering writing (EW) course from the HSSEAS writing course list or by selecting one approved Writing II (W) course. The course must be completed with a grade of C or better (C– or a Passed grade is not acceptable). Writing courses are listed in the Schedule of Classes at http://www.registrar.ucla.edu/soc/writing.htm.

Writing courses also approved for general education credit may be applied toward the relevant general education foundational area.

Technical Breadth Requirement

The technical breadth requirement consists of a set of three courses providing sufficient breadth outside the student’s core program. A list of HSSEAS Faculty Executive Committee-approved technical breadth requirement courses is available in the Office of Academic and Student Affairs, and deviations from that list are subject to approval by the associate dean for Academic and Student Affairs. None of the technical breadth requirement courses selected by students can be used to satisfy other major course requirements.

Ethics Requirement
The ethics and professionalism requirement is satisfied by completing one course from Engineering 183EW or 185EW with a grade of C or better (C– or a Passed grade is not acceptable). The course may be applied toward the engineering writing requirement.

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

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

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

GE courses used to satisfy the engineering writing and/or ethics requirements must be taken for a letter grade.

Requirements for Students Who Entered Fall Quarter 2005 and Thereafter

FOUNDATIONS OF KNOWLEDGE

General education courses are grouped into three foundational areas: Foundations of the Arts and Humanities, Foundations of Society and Culture, and Foundations of Scientific Inquiry.
Five courses (24 units minimum) are required. Engineering writing requirement courses also approved for GE credit may be applied toward the relevant GE foundational areas.

Students must meet with a counselor in the Office of Academic and Student Affairs to determine the applicability of GE Cluster courses toward the engineering writing or GE requirements.

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

Foundations of the Arts and Humanities

Two 5-unit courses selected from two different subgroups:
Literary and Cultural Analysis
Philosophical and Linguistic Analysis
Visual and Performance Arts Analysis and Practice

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

Foundations of Society and Culture
Two 5-unit courses, one from each subgroup:
- Historical Analysis
- Social Analysis

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

Foundations of Scientific Inquiry
One course (4 units minimum) from the Life Sciences subgroup or one course from Bioengineering CM145/Chemical Engineering CM145, Chemistry and Biochemistry 153A, or Civil and Environmental Engineering M166/Environmental Health Sciences M166:
- Life Sciences

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

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

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

Requirements for Students Who Entered Prior to Fall Quarter 2005
For the approved list of courses, see http://www.seas.oasa.ucla.edu/undergraduates/ge-home-page.

Department Requirements
Henry Samueli School of Engineering and Applied Science departments generally set two types of requirements that must be satisfied for the award of the degree: (1) Preparation for the Major (lower division courses) and (2) the Major (upper division courses). Preparation for the Major courses should be completed before beginning upper division work.

Preparation for the Major
A major requires completion of a set of courses known as Preparation for the Major. Each department sets its own Preparation for the Major requirements; see the Departments and Programs section of this announcement.

The Major
Students must complete their major with a scholarship average of at least a 2.0 (C) in all courses in order to remain in the major. Each course in the major department must be taken for a letter grade. See the Departments and Programs section of this announcement for details on each major.

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

Student Responsibility
Students should take advantage of academic support resources, but they are ultimately responsible for keeping informed of and complying with the rules, regulations, and policies affecting their academic standing.

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

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

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

Credit Limitations
Advanced Placement Examinations
Some portions of Advanced Placement (AP) Examination credit are evaluated by corresponding UCLA course number. If students take the equivalent UCLA course, a deduction of UCLA unit credit is made prior to graduation. See the AP Chart.

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

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

Foreign Language
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.

Repetition of Courses
For undergraduate students who repeat a total of 16 units or less, only the most recently earned letter grades and grade points are computed in the grade-point average (GPA). After repeating 16 units, the GPA is based on all letter grades assigned and total units attempted. The grade assigned each time a course is taken is permanently recorded on the transcript.

1. To improve the grade-point average (GPA), students may repeat only those courses in which they receive a grade of C– or lower; NP or U grades may be repeated to gain unit credit. Courses in which a letter grade is received may not be repeated on a P/ NP or S/U basis. Courses originally taken on a P/NP or S/U basis may be repeated on the same basis or for a letter grade.

2. Repetition of a course more than once requires the approval of the College or school or the dean of the Graduate Divi-
sion and is granted only under extraordinary circumstances.

3. Degree credit for a course is given only once, but the grade assigned each time the course is taken is permanently recorded on the transcript.

4. There is no guarantee that in a later term a course can be repeated (such as in cases when a course is deleted or no longer offered). In these cases students should consult with their academic counselor to determine if there is an alternate course that can be taken to satisfy a requirement. The alternate course would NOT count as a repeat of the original course.

**Minors and Double Majors**

HSSEAS students in good academic standing may be permitted a minor or double major. The minor or second major must be outside the school (e.g., Electrical Engineering major and Economics major). HSSEAS students are not permitted to double major with two school majors (e.g., Chemical Engineering and Civil Engineering). Students may file an Undergraduate Request to Double Major or Add Minor form at the Office of Academic and Student Affairs. The school determines final approval of a minor or double major request; review is done on a case by case basis, and filing the request does NOT guarantee approval.

While HSSEAS considers minor or double major requests, specializations are not considered at this time. Students interested in a minor or double major should meet with their counselor in 6426 Boelter Hall.

**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 freshman year.

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**

Students normally follow the curriculum in effect when they enter the school. California community college transfer students 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.

Students admitted to UCLA in Fall Quarter 2012 and thereafter use UCLA's Degree Audit System which can be accessed via URSA OnLine at http://www.ursa.ucla.edu. Students should contact their academic counselor in 6426 Boelter Hall with any questions.

Students admitted to UCLA prior to Fall Quarter 2012 use the HSSEAS Degree Audit Reporting System (DARS) and are able to view the credit they have received and determine which of their degree requirements are left to complete. See http://www.seasoasa.ucla.edu/undergraduates/DARS/

HSSEAS undergraduate students following a catalog year prior to 2005–06 should schedule an appointment with their academic counselor in 6426 Boelter Hall or by calling (310) 825-9580 to review course credit and degree requirements and for program planning.

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 logging in to CourseWeb (https://courseweb.seas.ucla.edu) and clicking on the “My Advisors” link.

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

**Honors**

**Dean's Honors List**

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

**Latin Honors**

Students who have achieved scholastic distinction may be awarded the bachelor’s degree with honors. Students eligible for 2013-14 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 3.861 or better) for *summa cum laude*, the next five percent (GPA of 3.760 or better) for *magna cum laude*, and the next 10 percent (GPA of 3.605 or better) for *cum laude*. The minimum GPAs required are subject to change on an annual basis. Required GPAs in effect in the graduating year determine student eligibility.

Based on grades achieved in upper division courses, engineering students must have a 3.861 grade-point average for *summa cum laude*, a 3.760 for *magna cum laude*, and a 3.605 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.
Master of Science in Engineering Online Degree

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

Master of Engineering Degree

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

Engineer Degree

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

Ph.D. Degrees

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

Established Fields of Study for the Ph.D.

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

Bioengineering Department

Biomedical instrumentation

Imaging, informatics, and systems engineering (biomedical signal and image processing, biosystems science and engineering, medical imaging informatics, neuroengineering)

Molecular cellular tissue therapeutics

Chemical and Biomolecular Engineering Department

Chemical engineering

Civil and Environmental Engineering Department

Civil engineering materials

Environmental engineering

Geotechnical engineering

Hydrology and water resources engineering

Structures (structural mechanics and earthquake engineering)

Computer Science Department

Artificial intelligence

Computational systems biology

Computer network systems

Computer science theory

Computer system architecture

Graphics and vision

Information and data management

Software systems

Electrical Engineering Department

Circuits and embedded systems

Physical and wave electronics

Signals and systems

Materials Science and Engineering Department

Ceramics and ceramic processing

Electronic and optical materials

Structural materials

Mechanical and Aerospace Engineering Department

Applied mathematics (established minor field only)

Applied plasma physics (minor field only)

Dynamics

Fluid mechanics

Heat and mass transfer

Manufacturing and design

Nanoelectromechanical/microelectromechanical systems (NEMS/MEMS)

Structural and solid mechanics

Systems and control

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

Admission

Applications for admission are invited from graduates of recognized colleges and universities. Selection is based on promise of success in the work proposed, which is judged largely on the previous college record. Candidates whose engineering background is judged to be deficient may be required to take additional coursework that 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 or refer to http://grad.ucla.edu/gasaa/admissions/INTLREQT.HTM.

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

Graduate Record Examination

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

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

Bioengineering

UCLA
5121 Engineering V
Box 951600
Los Angeles, CA 90095-1600

(310) 267-4985
fax: (310) 794-5258
e-mail: bioeng@ea.ucla.edu
http://www.bioeng.ucla.edu

Benjamin M. Wu, D.D.S., Ph.D., Chair
Daniel T. Kamei, Ph.D., Vice Chair

Professors
Denise Aberle, M.D.
Mark S. Cohen, Ph.D., in Residence
Ian A. Cook, M.D.
Linda L. Demer, M.D., Ph.D.
Timothy J. Deming, Ph.D.
James Dunn, M.D., Ph.D.
Robin L. Garrell, Ph.D.
Warren S. Grundfest, M.D., FACS
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor of Aeronautics)
Dean Ho, Ph.D.
Bahram Jalali, Ph.D.
Chang-Jin Kim, Ph.D.
Wentai Liu, Ph.D.
Chun看到了：[40x387]Liu, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Pei-Yu Chiou, Ph.D.
Chang-Jin Kim, Ph.D.
Yong Chen, Ph.D. (Mechanical and Aerospace Engineering)
Samson A. Chow, Ph.D. (Mechanical and Medical Pharmacology)
Joseph L. Demer, M.D., Ph.D. (Neurology, Ophthalmology)
Joseph J. DiStefano III, Ph.D. (Computer Science, Medicine)
Bruce S. Dunn, Ph.D. (Materials Science and Engineering)
V. Reggie Edgerton, Ph.D. (Integrative Biology and Physiology)
Alan Garfinkel, Ph.D. (Cardiology, Integrative Biology and Physiology)
Robert P. Gunsalus, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Vijay Gupta, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koeffler, M.D. (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
Eliot M. Landaw, M.D., Ph.D. (Biomathematics)
James C. Liao, Ph.D. (Chemical and Biomolecular Engineering)
Karen M. Lyons, Ph.D. (Molecular, Cell, and Developmental Biology, Orthopaedic Surgery)
Thomas G. Mason, Ph.D. (Chemistry and Biochemistry, Physics and Astronomy)
Heather D. Maynard, Ph.D. (Chemistry and Biochemistry)
Harry McKellop, Ph.D., in Residence (Orthopaedic Surgery)
Istan Mody, Ph.D. (Neurology, Physiology)
Harold G. Mombouquette, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D., in Residence (Medicine)
Peter M. Narins, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
Laurent Pilon, Ph.D. (Mechanical and Aerospace Engineering)
Zhlin Qu, Ph.D., in Residence (Cardiology, Medicine)
Dario L. Ringach, Ph.D. (Neurobiology, Psychology)
Desmond Smith, Ph.D. (Molecular and Medical Pharmacology)
Michael V. Sofroniew, M.D., Ph.D. (Neurobiology)
Igor Spigelman, Ph.D. (Dentistry)
Ren Sun, Ph.D. (Molecular and Medical Pharmacology)
Yi Tang, Ph.D. (Chemical and Biomolecular Engineering)
Ricky Taira, Ph.D., in Residence (Radiological Sciences)
Michael A. Teitell, M.D., Ph.D. (Pathology and Laboratory Medicine, Pediatrics)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
Paul M. Thompson, Ph.D., in Residence (Neurology)
James G. Tidball, Ph.D. (Integrative Biology and Physiology)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Arthur Toga, Ph.D. (Neurology)
Jack Van Horn, Ph.D. (Neurology)
Jeffrey Wang, M.D. (Orthopaedic Surgery)
David Wong, Ph.D. (Dentistry)
Lily Wu, Ph.D., M.D. (Molecular and Medical Pharmacology, Urology)
Z. Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics)

Professor Emeritus
Edward R.B. McCabe, M.D., Ph.D. (Mattel Executive Endowed Professor Emeritus of Pediatrics)

Associate Professors
Pei-Yu Chiu, Ph.D.
Dino Di Carlo, Ph.D.
Daniel T. Kamei, Ph.D.
Aydogan Ozcan, Ph.D.
Jacob J. Schmidt, Ph.D.

Assistant Professors
Daniel B. Ennis, Ph.D., in Residence
Andrea M. Kasiko, Ph.D.

Adjunct Professor
Howard Winet, Ph.D.

Adjunct Associate Professor
Bill J. Tawil, M.B.A., Ph.D.

Adjunct Assistant Professors
Martin O. Culjat, Ph.D.
Kayvan Niazi, Ph.D.
Shahrooz Rabizadeh, Ph.D.
Rahul Singh, Ph.D.

Affiliated Faculty

Professors
Marvin Bergsneider, M.D., in Residence (Neurosurgery)
Francisco Bezanilla, Ph.D. (Physiology)
Douglas L. Black, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)

Yong Chen, Ph.D. (Mechanical and Aerospace Engineering)
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Harold G. Mombouquette, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D., in Residence (Medicine)
Peter M. Narins, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
Laurent Pilon, Ph.D. (Mechanical and Aerospace Engineering)
Zhlin Qu, Ph.D., in Residence (Cardiology, Medicine)
Dario L. Ringach, Ph.D. (Neurobiology, Psychology)
Desmond Smith, Ph.D. (Molecular and Medical Pharmacology)
Michael V. Sofroniew, M.D., Ph.D. (Neurobiology)
Igor Spigelman, Ph.D. (Dentistry)
Ren Sun, Ph.D. (Molecular and Medical Pharmacology)
Yi Tang, Ph.D. (Chemical and Biomolecular Engineering)
Ricky Taira, Ph.D., in Residence (Radiological Sciences)
Michael A. Teitell, M.D., Ph.D. (Pathology and Laboratory Medicine, Pediatrics)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
Paul M. Thompson, Ph.D., in Residence (Neurology)
James G. Tidball, Ph.D. (Integrative Biology and Physiology)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Arthur Toga, Ph.D. (Neurology)
Jack Van Horn, Ph.D. (Neurology)
Jeffrey Wang, M.D. (Orthopaedic Surgery)
David Wong, Ph.D. (Dentistry)
Lily Wu, Ph.D., M.D. (Molecular and Medical Pharmacology, Urology)
Z. Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics)

Professor Emeritus
Tony F. Chan, Ph.D. (Mathematics)

Associate Professors
Alex Bu, Ph.D. (Radiological Sciences)
Katrina M. Dipple, M.D., Ph.D. (Human Genetics, Pediatrics)
Jeff D. Eldredge, Ph.D. (Mechanical and Aerospace Engineering)
Xiao Hu, Ph.D., in Residence (Neurosurgery, Surgery)
Y. Suntaek Ju, Ph.D. (Mechanical and Aerospace Engineering)
William S. Klug, Ph.D. (Mechanical and Aerospace Engineering)
Daniel S. Levi, Ph.D. (Pediatrics)
Dejan Markovic, Ph.D. (Electrical Engineering)
Matteo Pellegrini, Ph.D. (Molecular, Cell, and Developmental Biology)
Tatiana Segura, Ph.D. (Chemical and Biomolecular Engineering)
Hsiao-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
Danny JJ Wang, Ph.D., in Residence (Neurology)

Assistant Professors
James W. Bisley, Ph.D. (Neurobiology)
Louis S. Bouchard, Ph.D. (Chemistry and Biochemistry)
Christopher Giza, Ph.D., in Residence (Neurosurgery, Surgery)
Thomas G. Graeber, Ph.D. (Molecular and Medical Pharmacology)
Min Lee, Ph.D. (Dentistry)
Nader Pouratian, Ph.D. (Neurosurgery)
Amy C. Rowat, Ph.D. (Integrative Biology and Physiology)
Dan Ruan, Ph.D. (Radiation Oncology)
Ladan Shams, Ph.D. (Psychology)
Zhouwen Tu, Ph.D., in Residence (Neurology)
Michael R. van Dam, Ph.D. (Molecular and Medical Pharmacology)
Xinshu Grace Xiao, Ph.D. (Integrative Biology and Physiology)

Scope and Objectives
Faculty members in the Department of Bioengineering believe that the interface between biology and engineering is an exciting area for discovery and technology development in the twenty-first century. They have developed an innovative curriculum and created state-of-the-art facilities for cutting-edge research.

The bioengineering program is a structured offering 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. Combined with a strong emphasis on research, the program provides a unique engineering educational experience that responds to the growing needs and demands of bioengineering.
Department Mission
The mission of the Bioengineering Department is to perform cutting-edge research that benefits society and to train future leaders in the wide range of possible bioengineering careers by producing graduates who are well-grounded in the fundamental sciences, adept at addressing open-ended problems, and highly proficient in rigorous analytical engineering tools necessary for lifelong success.

Undergraduate Program Objectives
The bioengineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The goal of the bioengineering curriculum is to train future leaders by providing 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 five main program educational objectives: graduates (1) participate in graduate, professional, and continuing education activities that demonstrate an appreciation for lifelong learning, (2) demonstrate professional, ethical, societal, environmental, and economic responsibility (e.g., by active membership in professional organizations), (3) demonstrate the ability to identify, analyze, and solve complex, open-ended problems by creating and implementing appropriate designs, (4) work effectively in teams consisting of people of diverse disciplines and cultures, and (5) be effective written and oral communicators in their professions or graduate/professional schools.

Bioengineering B.S.
Capstone Major
Preparation for the Major
Required: Bioengineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B, 30BL; Computer Science 31; Life Sciences 2 (satisfies HSSEAS GE life sciences requirement), 3, 4, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Bioengineering 100, C106, 110, 120, 165EW (or Engineering 183EW or 185EW), 167L, 176, 180, Chemistry and Biochemistry 153A, Electrical Engineering 100; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Bioengineering 177A, 177B); and three major field elective courses (12 units) from Bioengineering C101, CM102, CM103, C104, C105, C131, CM140, CM145, C147, CM150, C170, C171, CM178, C179, 180L, 181, 181L, C183, C185, CM186, CM187, 199 (8 units maximum).

The three technical breadth and three major field elective courses may also be selected from one of the following tracks. Bioengineering majors cannot take bioengineering technical breadth courses to fulfill the technical breadth requirement.

Biomaterials and Regenerative Medicine: Bioengineering C104, C105, CM140, C147, C183, C185, 199 (8 units maximum), Materials Science and Engineering 104, 110, C111, 120, 130, 132, 140, 143A, 150, 151, 160, 161. The above materials science and engineering courses may be used to satisfy the technical breadth requirement.

Biomedical Devices: Bioengineering C131, C172, 199 (8 units maximum), Electrical Engineering 102, CM150 (or Mechanical and Aerospace Engineering CM180), Mechanical and Aerospace Engineering C187L. The electrical engineering or mechanical and aerospace engineering courses listed above may be used to satisfy the technical breadth requirement.

For Bioengineering 199 to fulfill a track requirement, the research project must fit within the scope of the track field, and the research report must be approved by the supervisor and vice chair.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study
For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

Bioengineering graduate students Henry Tse (left) and Mahdokht Masaedi (right) discuss research with Bioengineering professor Dino Di Carlo (middle).
The Bioengineering Department offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Bioengineering.

Bioengineering M.S.

Course Requirements

A minimum of 13 courses (44 units) is required, at least 10 of which must be from the 200 series, including three Bioengineering 290 courses and one 495 course. For the thesis plan, at least seven of the 13 must be formal courses and two must be 598 courses involving work on the thesis. For the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirements except for the subfield of medical imaging informatics where 2 units of course 597A are required. Lower division courses may not be applied toward graduate degrees. To remain in good academic standing, M.S. students must maintain an overall grade-point average of 3.0 and a grade-point average of 3.0 in graduate courses. By the end of the first term in residence, students design a course program in consultation with and approved by their faculty adviser.

Comprehensive Examination Plan

The comprehensive examination plan is available in all fields, and requirements vary for each field. Specific details are available from the graduate adviser. Students who fail the examination may repeat it once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are not permitted to submit a thesis and are subject to termination. The oral component of the Ph.D. preliminary examination is not required for the M.S. degree.

Thesis Plan

Every master’s degree thesis plan requires the completion of an approved thesis that demonstrates student ability to perform original independent research. New students who select this plan are expected to submit the name of the thesis adviser to the graduate adviser by the end of their first term in residence. The thesis adviser serves as chair of the thesis committee.

A research thesis (8 units of Bioengineering 598) is to be written on a bioengineering topic approved by the thesis adviser. The thesis committee consists of the thesis adviser and two other qualified faculty members who are selected from a current list of designated members for the graduate program.

Bioengineering Ph.D.

Course Requirements

To complete the Ph.D. degree, all students must fulfill minimum University requirements. Students must pass the Ph.D. preliminary examination, University Oral Qualifying Examination, and final oral examination, and complete the courses in Group I, Group II, and Group III under Fields of Study below. Also see Course Requirements under Bioengineering M.S. Students must maintain a grade-point average of 3.25 or better in all courses.

Written and Oral Qualifying Examinations

Academic Senate regulations require all doctoral students to complete and pass University written and oral qualifying examinations prior to doctoral advancement to candidacy. Under Senate regulations the University Oral Qualifying Examination is open only to students and appointed members of their doctoral committees. In addition to University requirements, some graduate programs have other precandidacy examination requirements. What follows are the requirements for this doctoral program. The Ph.D. preliminary examination tests a core body of knowledge, and requirements vary for each field. Specific details are available from the graduate adviser. Students who fail the examination may repeat it once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are subject to a recommendation for termination.

Within three terms after passing the Ph.D. preliminary examination, students are strongly encouraged 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 student preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

A doctoral committee consists of a minimum of four qualified UCLA faculty members. Three members, including the chair, are selected from a current list of designated inside members for the graduate program. The outside member must be a qualified UCLA faculty member who does not appear on this list.

A final oral examination (defense of the dissertation) is required of all students.

Fields of Study

Biomedical Instrumentation

The biomedical instrumentation (BMI) field is designed to train bioengineers interested in the applications and development of instrumentation used in medicine and biotechnology. Examples include the use of lasers in surgery and diagnostics, new microelectrical machines for surgery, sensors for detecting and monitoring of disease, microfluidic systems for cell-based diagnostics, new tool development for basic and applied life sciences research, and controlled drug delivery devices. The principles underlying each instrument and specific clinical or biological needs are emphasized. Graduates are targeted principally for employment in academia, government research laboratories, and the biotechnology, medical devices, and biomedical industries.

Course Requirements

Group I: Core Courses on General Concepts. At least three courses selected from Bioengineering C201, C204, C205, C206.

Group II: Field Specific Courses. At least three courses selected from Bioengineering CM202 (or CM203 or Molecular, Cell, and Developmental Biology 165A), CM250A, Electrical Engineering 100.

Group III: Field Elective Courses. The remainder of the courses must be selected from one of the following three areas:


Other electives are approved on a case-by-case basis.
Imaging, Informatics, and Systems Engineering

The imaging, informatics, and systems engineering (IIS) field consists of the following four subfields:

Biomedical Signal and Image Processing Subfield

The biomedical signal and image processing (BSIP) program prepares students for careers in the acquisition and analysis of biomedical signals and enables students to apply quantitative methods to extract meaningful information for both clinical and research applications. The program is premised on the fact that a core set of mathematical and statistical methods are held in common across signal acquisition and imaging modalities and across data analyses regardless of their dimensionality. These include signal transduction, characterization and analysis of noise, transform analysis, feature extraction from time series or images, quantitative image processing, and imaging physics. Students have the opportunity to focus their work over a broad range of modalities, including electrophysiology, optical imaging methods, MRI, CT, PET, and other tomographic devices, and/or on the extraction of image features such as organ morphometry or neurofunctional signals, and detailed anatomic/functional feature extraction. Career opportunities for BSIP trainees include medical instrumentation, engineering positions in medical imaging, and research in the application of advanced engineering skills to the study of anatomy and function.

Group I: Core Courses on General Concepts. Three courses selected from Bioengineering C201 (or CM286) and either CM202 and CM203, OR Molecular, Cell, and Developmental Biology 144 and Physiological Science 166.

Group II: Subfield Specific Courses. At least three courses selected from Biomedical Physics 205, M219, M248, Electrical Engineering 239AS, 266, Neurobiology M200C, Neuroscience CM272, M287, and one course from Bioengineering 165EW, Biostatistics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.


BioSystems Science and Engineering Subfield

Graduate study in biosystems science and engineering (BSSE) emphasizes the systems aspects of living processes, as well as their component parts. It is intended for science and engineering students interested in understanding biocontrol, regulation, communication, and measurement or visualization of biosystems (of aggregate parts—whole systems), for basic or clinical applications. Dynamic systems engineering, mathematical, statistical, and multiscale computational modeling and optimization methods—applicable at all biosystems levels—form the theoretical underpinnings of the field. They are the paradigms for exploring the integrative and hierarchical dynamical properties of biosystems quantitatively—at molecular, cellular, organ, whole organism, or societal levels—and leveraging them in applications. The academic program provides directed interdisciplinary biosystems studies in these areas, as well as quantitative dynamic systems biomodeling methods—integrated with the biology for specialized life sciences domain studies of interest to the students.

Typical research areas include molecular and cellular systems physiology, organ systems physiology, and medical, pharmacological, and pharmacogenomic systems studies, neurosystems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. The program fosters careers in research and teaching in systems biology/physiology, engineering, medicine, and/or the biomedical sciences, or research and development in the biomedical or pharmaceutical industry.

Group I: Core Courses on General Concepts. Two physiology/molecular, cellular, and organ systems biology courses from either Bioengineering CM202 and CM203, OR Photological Science 166 and Molecular Cellular, Cell, and Developmental Biology M140, OR 144 and another approved equivalent course, and two dynamic biosystems modeling, estimation, and optimization courses from Bioengineering CM286, and either Biostatistics 220 or 296B.


Group III: Subfield Ethics Course. One course selected from Bioengineering 165EW, Biostatistics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Medical Imaging Informatics Subfield

Medical imaging informatics (MII) is the rapidly evolving field that combines biomedical informatics and imaging, developing and adapting core methods in informatics to improve the usage and application of imaging in healthcare. Graduate study encompasses principles from across engineering, computer science, information sciences, and biomedicine. Imaging informatics research concerns itself with the full spectrum of low-level concepts (e.g., image standardization and processing, image feature extraction) to higher-level abstractions (e.g., associating semantic meaning to a region in an image, visualization and fusion of images with other biomedical data) and ultimately, applications and the derivation of new knowledge from imaging. Medical imaging informatics addresses not only the images themselves, but encompasses the associated (clinical) data to understand the context of the imaging study, to document observations, and to correlate and reach new conclusions about a disease and the course of a medical problem.

Research foci include distributed medical information architectures and systems, medical image understanding and applications of image processing, medical natural language processing, knowledge engineering and medical decision-support, and medical data visualization. Coursework is geared toward students with science and engineering backgrounds, introducing them to these areas in addition to providing exposure to fundamental biomedical informatics, imaging, and clinical issues. The area encourages interdisciplinary training with faculty members from multiple departments and emphasizes the practical translational development and evaluation of tools/applications to support clinical research and care.


Group II: Subfield Specific Courses. M.S. com-prehensive students must take three courses and Ph.D. students must take six
courses from any of the following concentrations:

Computer Understanding of Images: Biomedical Physics 210, 214, M219, M230, M266, Computer Science M266A, M266B, 276B, Electrical Engineering 211A


Information Networks and Data Access in Medical Environment: Computer Science 240B, 241A, 244A, 245A, 246


Group III: Subfield Ethics Course. One course selected from Bioengineering 165EW, Biomathematics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Neuroengineering Subfield

The neuroengineering (NE) subfield is designed to enable students with a background in biological sciences to develop and execute projects that make use of state-of-the-art technology, including microelectromechanical systems (MEMS), signal processing, and photonics. Students with a background in engineering 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. Trainees develop the capacity for the multidisciplinary teamwork, in intellectually and socially diverse settings, that is necessary for new scientific insights and dramatic technological progress in the 21st century. Students take a curriculum designed to encourage cross-fertilization of neuroscience and engineering. The goal is for neuroscientists and engineers to speak each other's language and move comfortably among the intellectual domains of the two fields.

Group I: Core Courses on General Concepts. Three courses selected from Bioengineering C201 (or CM286) and either CM202 and CM203, OR Molecular, Cell, and Developmental Biology 144 and Physiological Science 166.

Group II: Subfield Specific Courses. Bioengineering M260, M261A, M284, and one course from 165EW, Biomathematics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

Group III: Subfield Elective Courses. Two courses from one of the following two concentrations:


Neuroscience: Bioengineering C206, M263, Neuroscience M201, M202, 205

Molecular Cellular Tissue Therapeutics

The molecular cellular tissue therapeutics (MCTT) field covers novel therapeutic development across all biological length scales from molecules to cells to tissues. At the molecular and cellular levels, this research area encompasses the engineering of biomaterials, ligands, enzymes, protein-protein interactions, intracellular trafficking, biological signal transduction, genetic regulation, cellular metabolism, drug delivery vehicles, and cell-cell interactions, as well as the development of chemical/biological tools to achieve this.

At the tissue level, the field encompasses two subfields—biomaterials and tissue engineering. The properties of bone, muscles, and tissues, the replacement of natural materials with artificial compatible and functional materials such as polymers, composites, ceramics, and metals, and the complex interactions between implants and the body are studied at the tissue level. The research emphasis is on the fundamental basis for diagnosis, disease treatment, and redesign of molecular, cellular, and tissue functions. In addition to quantitative experiments required to obtain spatial and temporal information, quantitative and integrative modeling approaches at the molecular, cellular, and tissue levels are also included within this field. Although some of the research remains exclusively at one length scale, research that bridges any two or all three length scales is also an integral part of this field. Graduates are targeted principally for employment in academia, government research laboratories, and the biotechnology, pharmaceutical, and biomedical industries.

Course Requirements

Group I: Core Courses on General Concepts. At least three courses selected from Bioengineering C201, C204, C205, C206.

Group II: Field Specific Courses. At least three courses selected from Bioengineering 100, 110, 120, 176, CM278, C283, C285.


Other electives are approved on a case-by-case basis.

Faculty Areas of Thesis Guidance

Professors

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

Mark S. Cohen, Ph.D. (Rockefeller, 1985)
Rapid methods of MR imaging, fusion of electrophysiology and fMRI, advanced approaches to MR data analysis, ultra-low field MRI using SQUID detection, low-energy focused ultrasound for neurostimulation

Isa A. Cook, M.D. (Yale, 1987)
Brain function in normal states and cognitive disorders, blood brain barrier, effects of antidepressants on the brain, methods of treatment for mood disorders especially depression

Linda L. Demer, M.D., Ph.D. (Johns Hopkins, 1983)
Vascular biology, biomineralization, vascular calcification, mesenchymal stem cells

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

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

Robin L. Garrel, Ph.D. (U. Michigan, 1984)
Bioanalytical and surface chemistry with emphasis on fundamentals and applications of adhesion and wetting

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

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular mechanics, nanofluids, and nanomaterial research

Dean Ho, Ph.D. (UCLA, 2005)
Nanodiamond hydrogen-based drug delivery system, nanodiamond-embedded patch device as a localized drug-delivery implantable microfilm, nanoclank film technology for noninvasive localized drug delivery

Bahram Jalali, Ph.D. (Columbia, 1989)
RF photonics, fiber-optic integrated circuits, integrated optics, microwave photonics

Chang-Jin Kim, Ph.D. (UC Berkeley, 1991)
Microelectromechanical systems: micro/nano fabrication technologies, structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)

Wentai Liu, Ph.D. (Michigan, Ann Arbor, 1983)
Neural engineering

Molecular signaling (NF-κB and Wnt) tumor-invasive growth and metastasis, adult mesenchymal stem cells, dental stem cells and regen-
Lower Division Courses

10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields of bioengineering, including genetics, molecular biology, instrumention, and biological processing, biomechanics, biomaterials, tissue engineering, biotechnology, biological imaging, biomedical optics and lasers, neuromonitoring, and biomolecular machines. Letter grading. Mr. Deming (F)

19. Flat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current interest, led 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 contracts; 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. Enforced requisites: Mathematics 32A, Physics 1B. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamic analysis of biological systems. Material, energy, charge, and force balances. Introduction to network analysis. Letter grading. Mr. Kamei (W)

C101. Engineering Principles for Drug Delivery. (4) (Formerly numbered Biomedical Engineering C101.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33B, Physics 1B. Application of engineering principles for designing and understanding delivery of therapeutics. Discussion of physics and mathematics required for understanding colloidal stability. Application of concepts related to both modeling and experimentation of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion of drugs coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C201. Letter grading. Mr. Kamei (F)

CM102. Basic Human Biology for Bioengineers I. (4) (Formerly numbered Biomedical Engineering C102.) Lecture, four hours; discussion, one hour; outside study, seven hours. 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 fundamental aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM203. Letter grading. Mr. Grundfest (F)

CM103. Basic Human Biology for Bioengineers II. (4) (Formerly numbered Biomedical Engineering C103.) (Same as Physiological Science CM103.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, musculoskeletal, endocrine, immune, urinary, reproductive). System-specific modeling/simulations (immune regulation, wound healing, muscle mechanics and energetics, acid-base balance, excretion). Functional analysis of biomedical instruments (ultrasound, electrocardiogram, endoscopy, osteoporosis, blood gas analysis). Time permitting, offered as workshop. Not open for credit to Physiological Science majors. Concurrently scheduled with course CM204. Letter grading. Mr. Grundfest (W)

C104. Physical Chemistry of Biomacromolecules. (4) (Formerly numbered M104.) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 30A, Life Sciences 2, 3, 23L. To understand biological materials and design synthetic replacements, it is imperative to understand their physical chemistry. Biomacromolecules such as protein or DNA can be analyzed and characterized by applying fundamentals of polymer physical chemistry. Investigation of polymer structure and conformation, bulk and solution properties, and phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as protein conformation, solvation of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C204. Letter grading. Ms. Kasko (F)

C105. Engineering of Bioconjugates. (4) (Formerly numbered M105.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry involves combining molecules of widely different structures to produce compounds with wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depending on to be conjugated of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some applications. Concurrently scheduled with course C205. Letter grading. Mr. Deming (W)

C106. Topics in Biophysics, Channels, and Membranes. (4) (Formerly numbered M106.) Lecture, three hours; discussion, one hour; outside study, seven hours. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrostatics in dielectric media, building on complexity to ultimately address action potentials, propagation in nerves. Topics include Nerst/Plank and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course CM107. Letter grading. Mr. Schmidt (Not offered 2013-14)

C107. Polymer Chemistry for Bioengineers. (4) (Formerly numbered M107.) Lecture, four hours; discussion, one hour; outside study, seven hours. Required: course C104 or C105. Fundamental concepts of polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C207. Letter grading. Mr. Deming (W)

110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 100, Mathematics 33B. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body, and

C131. Nanopore Sensing. (4) (Formerly numbered M131.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, 23L, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artificial or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequenc- ing. Requisites: course CM140. Mr. Grundfest, Mr. Schmidt (W) 120. Biomedical Transducers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, 23L, Physics 1A, 1B, 1C. Overview of chemical and physical foundations of biomolecular science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of interactions that exist between biomolecu- cules, such as van der Waals interactions, entropically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, depletion interac- tions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery and tissue engineering. Prerequisite: course CM150L. Concurrently scheduled with course C231. Letter grading. Mr. Schmidt (Sp) 139A. Biomolecular Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomolecular science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of interactions that exist between biomolecu- cules, such as van der Waals interactions, entropically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, depletion interac- tions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery and tissue engineering. Prerequisite: course CM150L. Concurrently scheduled with course C231. Letter grading. Mr. Schmidt (Sp) 139B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course CM139B. Overview of chemical and physical foundations of biomolecular science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of interactions that exist between biomolecu- cules, such as van der Waals interactions, entropically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, depletion interac- tions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery and tissue engineering. Prerequisite: course CM150L. Concurrently scheduled with course C231. Letter grading. Mr. Schmidt (Sp) 140. Introduction to Biomechanics. (4) (Formerly numbered Biomedical Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, five hours. Emphasis on understanding of biological reactivity, emerging pathologies, and relationships to self-assembly processes. May be taken independently for credit. Concurrently scheduled with course CM140. Letter grading. Mr. Wong (W) 141L. Energy-Tissue Interactions II. (4) (Formerly numbered Biomedical Engineering C170.) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Corequisite: course C170L. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications, with em- phasis on understanding fundamental mechanisms underlying various types of energy-tissue interac- tions. Concurrently scheduled with course C270L. Letter grading. Mr. Grundfest (F) 142L. Introduction to Techniques in Studying Laser-Tissue Interaction. (4) Formerly numbered Biomedical Engineering C170L) Laboratory, four hours; outside study, two hours. Corequisite: course C170. Introduction to simulation and experimental tech- niques used in laboratory and clinical research. Topics include computer simulations of light propaga- tion in tissue, measuring absorption spectra of tis- sue/tissue phantoms, making tissue phantoms, de- termination of optical properties of different tissues, techniques of temperature distribution measure- ments. Concurrently scheduled with course C270L. Letter grading. Mr. Kamei (Sp) 143L. Hyperspectral Imaging and Spectroscopy. (4) (Formerly numbered Biomedical Engineering C171.) Lecture, four hours; discussion, eight hours. Requisites: course C170. Designed for physical sciences, life sciences, and engineering majors in hands-on approach to the design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biologic applications. Concurrently scheduled with course C171L. Letter grading. Mr. Grundfest (W) 144L. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) (Formerly numbered Biomedical Engineering C171.) Lecture, four hours; outside study, eight hours. Requisites: course C170. Designed for physical sciences, life sciences, and engineering majors in hands-on approach to the design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biologic applications. Concurrently scheduled with course C171L. Letter grading. Mr. Grundfest (W) 145L. Molecular Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Selected topics in molecular biology that form foun- dation of biotechnology and biomedical industry to- day. Topics include recombinant DNA technology, monoclonal antibodies, and directed mutagenesis and expression, directed mutagenesis and protein engineer- ing, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, gene therapy, and tissue engineering. Concurrently sched- uled with course CM245. Letter grading. Mr. Liao (F) 146L. Applied Tissue Engineering: Clinical and In- dustry Perspective. (4) (Formerly numbered Bio- medical Engineering C147.) Lecture, three hours; dis- cussion, two hours; outside study, seven hours. Re- quisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, producing functional artificial tis- sues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/ biochemical engineering of tissues. Requisites include skin and artificial skin, bone and cartilage, blood ves- sels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering. Methods of microfabrica- tion, clinical limitations, and regulatory challenges in design and development of tissue-engineering de- vices. Concurrently scheduled with course C247. Letter grading. Mr. Wu (F) 148L. Introduction to Micromachining and Mi- croelectromechanical Systems (MEMS). (4) (Formerly numbered Biomedical Engineering CM150.) Introduction to microfabrication technologies and microelectromechanical sys- tems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microfluidic de- vice, microfabrication processes capable of achieving desired MEMS de- vice. Concurrently scheduled with course CM250L. Letter grading. Mr. Choiou (F) 150. Introduction to Micromachining and Mi- croelectromechanical Systems (MEMS) Laborato- ry. (2) (Formerly numbered Biomedical Engineering CM150L.) Lecture, one hour; laboratory, three hours. Requisites: course CM150, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining technolo- gies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microfluidic devices, and microactuators. Students design microfabrication processes capable of achieving desired MEMS de- vice. Concurrently scheduled with course CM250L. Letter grading. Mr. Choiou (F) 150L. Introduction to Micromachining and Mi- croelectromechanical Systems (MEMS) Laboratory. (2) (Formerly numbered Biomedical Engineering CM150L.) Lecture, one hour; laboratory, three hours. Requisites: course CM150, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining technolo- gies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microfluidic devices, and microactuators. Students design microfabrication processes capable of achieving desired MEMS de- vice. Concurrently scheduled with course CM250L. Letter grading. Mr. Choiou (F) 153L. Laser-Tissue Interaction of Struc- tured Interfaces in Microflows. (4) Lecture, four hours; labora- tory, one hour; outside study, seven hours. Enforced requisites: course 110. Introduction to Navier/Stokes equations, assumptions, and simplifications. Analyti- cal framework for developing and nu- merical methods to solve and gain intuition for com- plex flows. Forces on particles in Stokes flow and fi- nite-inertia flows. Fluids flowing around particles with emphasis on dielectrophoretic forces, particle- particle interactions. Secondary flows in- duced by structures and particles in confined flows. Particle separations by fluid dynamic forces: field- flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biologi- cal flows and separations for biotechnology. Helps students become sufficiently fluent with fluid me- chanics vocabulary and techniques to model microfluidic systems to manipulate fluids, cells, and particles, and develop strong intuition for how fluid and particles behave in arbitrarily structured microchannels over range of Reynolds numbers. Concurrently scheduled with course C153. Letter grading. Mr. Di Carlo (Sp)
177A. Bioengineering Capstone Design I. (4) (Formerly numbered 182B.) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: courses 167L, 176. Lectures, seminars, and discussions on topics of biomedical device and therapeutic design, including topics such as need finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to address current problems in medicine and engineering. Source and ordering of materials and supplies relevant to student projects. Exploration of different experimental and computational methods. Scientific presentation of project results. Mr. Di Carlo, Mr. Wong (F)

177B. Bioengineering Capstone Design II. (4) (Formerly numbered 182C.) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: courses 177A, upper division courses in medicine, engineering, and biology. Students conduct directed experiments and computational modeling, give oral presentations, write reports, and participate in bioengineering design competition. Letter grading. Mr. Di Carlo, Mr. Wong (W)

CM178. Introduction to Biomaterials. (4) (Formerly numbered Biomedical Engineering CM180.) (Same as Materials Science CM181.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: courses 20A, 20B, 20L, or Materials Science 104. Engineering materials used in medicine and industry. Focus on current problems in medicine and engineering. Source and ordering of materials and supplies relevant to student projects. Exploration of different experimental and computational methods. Scientific presentation of project results. Mr. Di Carlo, Mr. Wong (W)

CM184. Introduction to Computational and Systems Biology. (2) (Formerly numbered Biomedical Engineering M184.) (Same as Computational and Systems Biology M184 and Computer Science M184.) Lecture, three hours; discussion, three hours. Corequisites: courses 31A, 31B. Survey course designed to introduce students to computational and systems biology. Focus on current interest in scientific community, appropriate for students with computational and systems biology research background. Letter grading. Mr. DiStefano (F)

CM185. Introduction to Tissue Engineering. (4) (Formerly numbered Biomedical Engineering C185.) Lecture, three hours; discussion, one hour; outside study, eight hours. Corequisites: courses CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three-dimensional construct: cells, scaffolds, and molecular signals. Concurrently scheduled with course C285. Letter grading. Mr. DiStefano (W)

CM186. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered Biomedical Engineering CM186.) (Same as Computational and Systems Biology CM186 and Computer Science CM186L.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electrical Engineering 102. Dynamic bio-systems modeling and computer simulation methods for understanding biological and physiological processes and systems at multiple levels of organization. Control system, multicompartmental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biocomputational pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomedicine/engineering/mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PO laboratory assignments. Concurrently scheduled with course CM187. Letter grading. Mr. DiStefano (F)

CM187. Research Communication in Computational and Systems Biology. (2 to 4) (Formerly numbered Biomedical Engineering CM187.) (Same as Computational and Systems Biology M187.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Closely directed, interactive, and real research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critical reviews of oral presentations and written reports and explain how to proceed with research for research projects. May be repeated once for credit. Letter grading.

Graduate Courses

C201. Engineering Principles for Drug Delivery. (4) (Formerly numbered Biomedical Engineering C201.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33B, Physics 1B. Application of engineering principles for designing and understanding delivery of therapeutics. Discussion of physics and mathematics required for understanding colloid stability. Analysis of concepts relevant to the modeling and experimentation of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion of drugs, coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C101. Letter grading. Mr. Kamei (F)

CM202. Basic Human Biology for Bioengineers I. (4) (Formerly numbered Biomedical Engineering CM202.) Lecture, four hours; laboratory, two hours; preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Sciences majors. Broad overview of physiological activities and organization of human body in system (organ/tissue) to system, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demon-
stratification of biomedical instruments, as well as visits to healthcare environments. Emphasis is placed on the understanding of the physical principles governing the design and operation of biomedical devices. Topics include Nernst-Planck and Poisson/Boltzmann equations, and separation and characterization of biological specimens. Projects focus on medical information retrieval, with an emphasis on understanding data and process modeling, in biomaterials. Basic concepts of chemical ligands, including design and synthesis of synthetic conjugates for sample applications. Coursed with course C105. Letter grading. Mr. Deming (W).

C204. Physical Chemistry of Biomacromolecules. (4) (Formerly numbered Biomedical Engineering C204.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B. To understand biological materials and design synthetic replacements, it is imperative to understand their physical chemistry. Biomacromolecules such as protein or DNA can be manipulated to design new materials. Basic concepts include fundamentals of polymer physical chemistry. Investigation of polymer structure and conformation, and solution thermodynamics and phase behavior, polymer solutions, and biological applications. Applications engineering principles to problems involving biomacromolecules such as protein conformation, solvation of charged species, and separation and characterization of biologically important macromolecules. Concepts presented with practical experience. Projects focus on medical information retrieval, with an emphasis on understanding data and process modeling, in biomaterials. Basic concepts of chemical ligands, including design and synthesis of synthetic conjugates for sample applications. Coursed with course C105. Letter grading. Mr. Deming (W).

C205. Engineering of Bioconjugates. (4) (Formerly numbered Biomedical Engineering C205.) Lecture, four hours; laboratory, two hours; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Glycolconjugates may be coupled to a surface in gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of biological conjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depends on the molecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic conjugates for some sample applications. Coursed with course C105. Letter grading. Mr. Deming (W).

C206. Topics in Biophysics, Channels, and Membranes. (4) (Formerly numbered Biomedical Engineering C206.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4; Mathematics 33B; Physical Chemistry of Biomacromolecules. Emphasis on understanding the physical principles governing electrodynamics in dielectric media, building on complexity to ultimately address action potentials and signaling in neurons. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C106. Letter grading.

Mr. Schmidt (Not offered 2013-14)

C207. Polymer Chemistry for Bioengineers. (4) (Formerly numbered Biomedical Engineering C207.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course C204 or C205. Fundamental concepts of polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and shape. Concepts include copolymerization and stereochemistry in polymerizations. Presentation of applications of use of different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerization and stereochemistry in polymerizations. Topics include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C107. Letter grading. Mr. Deming (W).

M214A. Digital Speech Processing. (4) (Formerly numbered Biomedical Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, eight hours. Requisite: course C104. Letter grading. Mr. Astrid (F).

M215. Biochemical Reaction Engineering. (4) (Formerly numbered Biomedical Engineering M215.) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4; Mathematics 221. Corequisite: course C104. Letter grading. Ms. Alwan (W).

M217. Biomedical Imaging. (4) (Formerly numbered Biomedical Engineering M217.) (Same as Electrical Engineering E224A.) Lecture, three hours; outside study, nine hours. Requisite: Electrical Engineering 114 or 211A. Optical imaging modalities in biomedicine. Other nonoptical imaging modalities discussed briefly. Topics include magnetic resonance, computed tomography, ultrasound, and optical imaging. Concepts presented with practical experience. Projects focus on medical information retrieval, with an emphasis on understanding data and process modeling, in biomaterials. Basic concepts of chemical ligands, including design and synthesis of synthetic conjugates for sample applications. Coursed with course C105. Letter grading.

M220. Introduction to Medical Informatics. (2) (Formerly numbered Biomedical Engineering 220.) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to a field. Definition of this emerging field of study, current research efforts, and future directions in research. Key issues in medical informatics to expose students to different application domains, such as electronic health records, computerized clinical applications, data and process modeling, in biomaterials. Basic concepts of chemical ligands, including design and synthesis of synthetic conjugates for sample applications. Coursed with course C105. Letter grading. Mr. Kangaro (F).

M221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) (Formerly numbered Biomedical Engineering M221.) Lecture, four hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understanding and visualizing of anatomy and physiology through medical images. Topics relevant to acquisition, representation, and dissemination of anatomical knowledge in computerized clinical applications. Topics include chemistry, gastrointes-

M222A. Programming Laboratories for Medical and Imaging Informatics I, II, III. (4-4-4) (Formerly numbered Biomedical Engineering M222A.) Lecture, two hours; discussion, one hour; outside study, seven hours. Corequisite: Chemical Engineering CM222A. Separation strategies, with an emphasis on design processes for isolating and purifying materials like whole cells, en-
zymes, food additives, or pharmaceuticals that are products of biological reactors. Letter grading.

Mr. Monbouquette (W)

M226. Medical Knowledge Representation. (4) (Formerly numbered Biomedical Engineering M226.) (Same as Information Studies M252.) Seminar, four hours; outside study, eight hours. Designed for graduate students. Introduction to natural language processing and information extraction approaches and their application in healthcare processes. Topics include data structures used for representing knowledge (conceptual graphs, frame-based systems, ontologies), data models for representing spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (data mining, statistical classifiers, and hierarchical clustering techniques), 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). Letter grading. Mr. Taia (Sp)

M227. Medical Information Infrastructures and Internet Technologies. (4) (Formerly numbered Biomedical Engineering M227.) (Same as Information Studies M253.) Lecture, four hours; outside study, seven hours. Designed for graduate students. Introduction to networking, communications, and information infrastructures in medical environment. Exposure to topics related to networking and communication at several layers: low-level (TCP/IP, services), medium-level (network topologies), and high-level (distributed computing, Web-based services) implementations. Consideration of each layer. Use of communication protocols (H.71, DICOM) and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless health systems, peer-to-peer topologies, grid/cloud computing. Introduction to security and encryption in networked environments. Letter grading.

Mr. Bui (F)

M228. Medical Decision Making. (4) (Formerly numbered M228) (Same as Information Studies M255) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and algorithmic techniques for decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing, and estimation. Focus on technical advances in medical decision support systems (artificial intelligence) with review of a selection of current research. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading.

Mr. Konkar (W)

C231. Nanopore Sensing. (4) (Formerly numbered Biomedical Engineering C231) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, 23L, Physics 1A, 1B, 1C. Analysis of sensors based on measurements of fluctuating ionic conductance through artificial or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and instrumentation of electrical measurements in electronic circuits, ionic conduction through pores and GHK equation, patch clamp and single channel measurements and instrumentation, noise issues, protein engineering, molecular sensing, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C131. Letter grading.

Mr. Schmidt (F)

C23A. Advancing Bioengineering Innovations I: Unmet Needs. (4) Lecture, three hours; discussion, three hours; laboratory, three hours; outside study, eight hours. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Focus on understanding how to identify unmet clinical needs, properly filtering through these needs using various acceptance criteria, and selecting promising needs for which potential medical solutions are explored. Students work in groups to expedite traditional research and development processes to invent and implement new medtech devices that increase quality of clinical care and result in improved patient outcomes in hospital system. Introduction to intellectual property basics and various medtech business models. Letter grading. Mr. Wu (W)

C23B. Advancing Bioengineering Innovations II: Developing and Implementing Medtech Solutions. (4) Lecture, three hours; outside study, nine hours. Emphasis on various aspects of development of medtech for clinical need. Topics include strategies for necessary to commercialize viable medtech solutions. Exploration of concept selection, business plan development, intellectual property filing, financing strategies, and device prototyping. Letter grading.

Mr. Grundfest, Mr. Liu, Mr. Shikumar, Mr. Wu (Sp)

C239A. Biomolecular Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical fundamental properties of biomolecular materials. Emphasis on concern materials aspects of molecular biology, cell biology, and tissue engineering. Understanding of different types of interactions that exist between biomolecules, e.g., hydrogen bond, hydrophobic interaction, salt bridge, van der Waals force, covalent bond, ionic bond, polarization, and electrostatic interactions. Introduction to common biomaterials and their synthesis. Introduction to common syntheses of biomaterials, including biodegradable polymers and non-biodegradable polymers. Letter grading.

Mr. Schlenoff (Sp)

C239B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course C239A is not requisite to course C239B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of biomolecules, with emphasis on nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into their functional forms via self-assembly and how these structures imparts functions, including the use of examples from bioengineering and biomedical engineering. Case study on current topics, including drug delivery, gene therapy, cancer therapeutics, emerging materials and self-assembling to disease states. May be taken independently for credit. Concurrently scheduled with course C139B. Letter grading.

Mr. Wu (Sp)

CM240. Introduction to Biomechanics. (4) (Formerly numbered Biomedical Engineering CM240) (Same as Mechanical and Aerospace Engineering CM240) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aerospace Engineering 18A, 18B. Introduction to mechanical functions of human body; skeletal adaption to optimize load transfer, mobility, and function. Dynamics and kinesics. Fluid mechanics and the role of proper aerodynamics. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

Mr. Gupta (W)

CM245. Molecular Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM245) (Same as Chemical Engineering CM245) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 3, 23L. Selection and design of biomolecular systems that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading.

Mr. Liao (F)

C247. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) (Formerly numbered Biomedical Engineering C247) Lecture, three hours; discussion, one hour, outside study, eight hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, Biological Engineering 156A. Focus on how to build artificial tissues, organs, and tissues using advanced technologies. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin, cartilage, skeletal muscle, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C147. Letter grading.

Mr. Wu (F)

C248. Introduction to Tissue Engineering. (4) (Formerly numbered Biomedical Engineering CM248) (Same as Biomedical Physics M248 and Pharmacology M248.) Lecture, three hours; laboratory, one hour; outside study, seven hours. Exploration of role of bioengineering in medicine. Topics include imaging physics, immunization, imaging process, and applications of imaging for range of modalities. Practical experience provided through series of hands-on laboratories. Letter grading.

CM250A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Formerly numbered Biomedical Engineering CM250A) (Same as Electrical Engineering CM250A and Mechanical and Aerospace Engineering CM280A) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, Mechanical and Aerospace Engineering 156A. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM150. Letter grading.

CM250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Formerly numbered Biomedical Engineering M250B.) (Same as Electrical Engineering M250B and Mechanical and Aerospace Engineering M280B) Lecture, three hours; laboratory, one hour; outside study, eight hours. Enforced requisite: course CM150 or CM250A. 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. Candler (Sp)

CM250L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Formerly numbered Biomedical Engineering M250L) (Same as Electrical Engineering CM250L and Mechanical and Aerospace Engineering CM280L) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM250A, CM250B, Mechanical and Aerospace Engineering 156L, 4BL. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM150L. Letter grading.

Mr. Chiu (W)

M252. Microelectromechanical Systems (MEMS) Design, Fabrication and Testing. (4) (Formerly numbered Biomedical Engineering M252.) (Same as Electrical Engineering M252 and Mechanical and Aerospace Engineering M282) Lecture, four hours; outside study, seven hours. Requisites: course CM250A, CM250B, Mechanical and Aerospace Engineering 156A. Focus on design, fabrication, and testing of MEMS. Topics include: MEMS fabrication processes, microactuators material properties, and design. Letter grading.
C270. Energy-Tissue Interactions. (4) Formerly numbered Biomedical Engineering C270.) Lecture, three hours; outside study, nine hours. Requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Introduction to therapeutic and diagnostic use of energy delivery devices in medical and dental applications, with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C170L. Letter grading. Mr. Grundfest (F).

C270L. Introduction to Techniques in Studying La- ter-Tissue Interaction. (2) Formerly numbered Bio- medical Engineering C270L.) Lecture, four hours; outside study, two hours. Corequisite: course C270. Introduction to simulation and experimental tech- niques used in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissue/tissue phantoms, making tissue phantoms, de- termination of optical properties of different tissues, techniques of temperature distribution measure- ments. Concurrently scheduled with course C170L. Letter grading.


C272. Design of Minimally Invasive Surgical Tools. (4) Formerly numbered Biomedical Engineering C272.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, 23L, Mathematics 32A, 32B, 33A, 33B, Physics 1A, 1B, 1C. Introduction to physics of motor proteins and cytoskele- ton: muscle, actin and myosin, forces and forces at- tachment, myofilament mechanics, calcium action, fatigue, signal transduction. Mechanical properties and behavior of living systems. Topics include biological systems, design and develop- ments, design and development of novel drug delivery systems that can provide spatial and temporal control of drug re- lease. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and compounds used in delivery and re- lease. Concurrently scheduled with course C185. Letter grading. Ms. Liu (Sp).

M260. Neuroengineering. (4) Formerly numbered Biomedical Engineering M260.) (Same as Electrical Engineering EE M260.) Lecture, three hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. Introduction to the fundamental properties of bioelectronics and neural signal recording, processing and stimulation. Topics include bioelectricity, electro- physiology, EEG and ECOG, EEG and extracellular recording, microelectrodes, neural interfaces, neural signal processing, signal filtering, spike detection, spike sorting, transduction of thermal, mechanical, electrochemical and optical signals. Introduction to neural recording techniques. Concurrently scheduled with course C186. Letter grading. Mr. Wu (W).

M261A-M261B-M261C. Evaluation of Research Literature in Neuroengineering. (2-2-2) Formerly numbered Biomedical Engineering M261A-M261B- M261C.) (Same as Electrical Engineering EE M261A- M261B-M261C.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. Introduction to research and development framework for calculating simple flows and nu- merical methods to solve and gain intuition for com- plex flows. Forces on particles in Stokes flow and fi- nite-inertia flows. Fluids around moving bodies. For- ces on particles in confined flows. Direction on how to proceed with search for research results. Ma-
Urban emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading. Mr. DiStefano (Sp)

295A-295Z. Seminars: Research Topics in Biomedical Engineering. (1 to 4) (Formerly numbered Biomedical Engineering 295A-295Z) Seminar, one to four hours. Limited to bioengineering graduate students. Advanced study and analysis of current topics in bioengineering. Discussion of current research literature and research in the interest of specialty faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit. S/U grading.

295A. Biomedical Research.

295B. Biomaterials and Tissue Engineering Research.

295C. Minimaly Invasive and Laser Research.

295D. Hybrid Device Research.

295E. Molecular Cell Biotechnology Research.

295F. Biopolymer Materials and Chemistry.

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

M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Formerly numbered Biomedical Engineering M296B) (Same as Biostatistics M270, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biostatistics 220. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W)

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

M296D. Introduction to Computational Cardiology. (4) (Formerly numbered Biomedical Engineering M296D.) (Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological processes, chaotic models of action potential (AP), Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading. Mr. Kogan (F;Sp)

298. Special Studies in Biomechanical Engineering. (4) (Formerly numbered Biomedical Engineering 298.) Lecture, four hours; outside study, eight hours. Study of selected topics in biomechanical engineering taught by resident and visiting faculty members. May be repeated for credit. Letter grading.

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

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

495. Teaching Assistant Training Seminar. (2) (Formerly numbered Biomedical Engineering 495.) Seminar, two hours; outside study, four hours. Limited to graduate bioengineering students. Required of all departmental teaching assistants. May be taken concurrently while holding TA appointment. Seminar on communicating bioengineering and biomedical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids, grading, advising, and rapport with students. S/U grading. Mr. Kamei (F)

596. Directed Individual or Tutorial Studies. (2 to 8) (Formerly numbered Biomedical Engineering 596.) Tutorial, to be arranged. Limited to graduate bioengineering students. Petition forms to request enrollment and may be obtained from program office. Supervised study and analysis of current topics in bioengineering. S/U grading.

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

597B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) (Formerly numbered Biomedical Engineering 597B.) Tutorial, to be arranged. Limited to graduate bioengineering students. S/U grading.

597C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) (Formerly numbered Biomedical Engineering 597C.) Tutorial, to be arranged. Limited to graduate bioengineering 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) (Formerly numbered Biomedical Engineering 598.) Tutorial, to be arranged. Limited to graduate bioengineering 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) (Formerly numbered Biomedical Engineering 599.) Tutorial, to be arranged. Limited to graduate bioengineering students. Usually taken after students have been advanced to candidacy. S/U grading.

Chemical and Biomolecular Engineering

UCLA

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e-mail: chemeng@ucla.edu
http://www.chemeng.ucla.edu

James C. Liao, Ph.D., Chair
Yi Tang, Ph.D., Vice Chair

Professors
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Panagiota D. Christofides, Ph.D.
Yoram Cohen, Ph.D.
James F. Davis, Ph.D., Vice Provost
Vijay K. Dhir, Ph.D., Dean
Robert F. Hicks, Ph.D.
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering)
Yunfeng Lu, Ph.D.
Vasilios I. Manousiouthakis, Ph.D.
Harold G. Monbouquette, Ph.D.
Seil M. Senkan, Ph.D.
Yi Tang, Ph.D., Chancellor's Professor

Professors Emeriti
Louis J. Ignarro, Ph.D. (Nobel laureate, Jerome J. Belzer Professor Emeritus of Medical Research)
Eldon L. Knuth, Ph.D.
Ken Nobe, Ph.D.
William D. Van Vorst, Ph.D.
Vincent L. Vilkov, Ph.D.
A.R. Frank Wazzan, Ph.D., Dean Emeritus

Associate Professor
Tatiana Segura, Ph.D.

Assistant Professors
Yvonne Y. Chen, Ph.D.
Gerassimos Orkoulas, Ph.D.

Scope and Objectives

The Department of Chemical and Biomolecular Engineering conducts undergraduate and graduate programs in teaching and research that focus on the areas of biomedical engineering, systems engineering, and advanced materials processing and span the general themes of energy/environment and nanotechnology. Aside from the fundamentals of chemical engineering (thermodynamics, transport phenomena, kinetics, reactor engineering and separations), particular emphasis is given to metabolic engineering, protein engineering, synthetic biology, bio-nano-technology, biomaterials, air pollution, environmental modeling, pollution prevention, molecular simulation, pro-
cess systems engineering, membrane science, semiconductor processing, chemical vapor deposition, plasma processing, and polymer engineering.

Students are trained in the fundamental principles of these fields while acquiring sensitivity to society’s needs—a crucial combination needed to address the challenge of continued industrial growth and innovation in an era of economic, environmental, and energy constraints.

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

**Undergraduate Mission and Program Objectives**

The chemical engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The mission of the undergraduate program is to educate future leaders in chemical and biomolecular engineering who effectively combine their broad knowledge of physics, chemistry, biology, and mathematics 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 and biomolecular engineering alumni who (1) 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) incorporate social, ethical, environmental, and economical considerations, including the concept of sustainable development, into chemical and biomolecular engineering practice, (3) lead or participate successfully on multidisciplinary teams assembled to tackle complex multi-faceted problems that may require implementation of both experimental and computational approaches and a broad array of analytical tools, and (4) pursue graduate study and achieve an M.S. or Ph.D. degree in the sciences and engineering and/or achieve success as professionals in chemical and biomolecular engineering as well as related fields, including business, medicine, and environmental protection.

**Undergraduate Study**

The Chemical Engineering major is a designated capstone major. The capstone project requires students to first work individually and learn how to integrate chemical engineering fundamentals taught in prior required courses; then work in groups to produce a paper design of a realistic chemical process using appropriate software tools. Graduates should be able to design a chemical or biological system, component, or process that meets technical and economical design objectives, with consideration of environmental, social, and ethical issues, as well as sustainable development goals. In addition, they should be able to apply their knowledge of mathematics, physics, chemistry, biology, and chemical and biological engineering to analysis and design of chemical and biochemical processes and products; function on multidisciplinary teams; identify, formulate, and solve complex chemical and biological engineering problems; and communicate effectively, both orally and in writing.

**Chemical Engineering B.S.**

**Capstone Major**

The chemical engineering curricula provide a high quality, professionally oriented education in modern chemical engineering. The biomedical engineering, biomolecular engineering, environmental engineering, and semiconductor manufacturing engineering options provide students an opportunity for exposure to a subfield of chemical and biomolecular engineering. In all cases, balance is sought between engineering science and practice.

**Chemical Engineering Core Option**

**Preparation for the Major**

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

**The Major**

**Required:** Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomedical elective course (4 units) from Chemical Engineering C115, C121, C124, C125, CM127, C135, or CM145 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ges/.

**Biomedical Engineering Option**

**Preparation for the Major**

**Required:** Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Computer Science 31; Life Sciences 2, 3, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

**The Major**

**Required:** Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 104A, 104D, 104DL, 107, 109, C115, C125, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one biomedical elective course (4 units) from Chemical Engineering C124, CM127, C135, or CM145 (course CM145 is recommended; another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on University and general education requirements, see Requirements
for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Environmental Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, Atmospheric and Oceanic Sciences 104, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and two elective courses (8 units) from Chemical Engineering 113, C118, C119, C121, C135, C140 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Semiconductor Manufacturing Engineering Option

Preparation for the Major

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

The Major

Required: Chemical Engineering 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104C, 104CL, 106, 107, 109, C116, Chemistry and Biochemistry 113A, 153A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and one elective course (4 units) from Materials Science and Engineering 104, 120, 121, 122, or 150 plus one elective course (4 units) from Electrical Engineering 2, 100, 121B, 123A, or 123B.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22.

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

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

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

Chemical Engineering M.S.

Areas of Study

Consult the department.

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

Course Requirements

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

All M.S. students are required to enroll in the seminar, Chemical Engineering 299, during each term in residence.

A program of study that encompasses these requirements must be submitted to the departmental Student Affairs Office for approval before the end of the student's second term 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 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, M152B, 199; Electrical Engineering 100, 101A, 102, 103, 110L, M116L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 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/104CL, C216, 270, 270R, Electrical Engineering 123A, Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical engineering or materials science and engineering electives must be selected, with a minimum of two at the 200 level. A total of at least five graduate (200-level) courses is required. Approved elective courses include Chemical Engineering C214, C218, C219, C223, C240, Electrical Engineering 221A, 221B, 223, Materials Science and Engineering 210, 223.

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 term in residence.

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

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

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

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

Chemical Engineering Ph.D.

Major Fields or Subdisciplines
Consult the department.

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

All Ph.D. students are required to enroll in the seminar, Chemical Engineering 299, during each term in residence.

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

Written and Oral Qualifying Examinations
Academic Senate regulations require all doctoral students to complete and pass University written and oral qualifying examinations prior to doctoral advancement to candidacy. Under Senate regulations the University Oral Qualifying Examination is open only to students and appointed members of their doctoral committees. In addition to University requirements, some graduate programs have other precandidacy examination requirements. What follows are the requirements for this doctoral program.

All entering Ph.D. students are required to undergo a preliminary oral evaluation (POE) normally scheduled at the beginning of Fall Quarter. This evaluation by a faculty committee assesses student understanding of chemical and biomolecular engineering fundamentals in the areas of the required core graduate courses. The POE outcome consists of a recommendation of a course plan for the students that ultimately can lead to successful completion of the course requirements for the Ph.D. degree.

After completion of the required courses for the degree, students must pass the written and oral qualifying examinations. These examinations focus on the dissertation research and are conducted by a doctoral committee consisting of at least four faculty members nominated by the department in accordance with University regulations.

Three members, including the chair, are inside members and must hold faculty appointments in the department. The outside member must be a UCLA faculty member in another department. Students are required to have a 3.33 grade-point average in graduate coursework to be eligible to take these examinations.

The written qualifying examination consists of a dissertation research proposal that provides a clear description of the problem(s) considered, a literature review of the current state of the art, and a detailed explanation of the research plan that is to be followed to solve the problem(s). Students normally submit their dissertation research proposals to their doctoral committees before the end of Winter Quarter of the second year in academic residence.

The University Oral Qualifying Examination consists of an oral defense of the dissertation research proposal and is administered by the doctoral committee. The written research proposal must be submitted to the committee at least two weeks prior to the oral examination to allow the members sufficient time to evaluate the work.

Facilities

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

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

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

Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory

The Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory is equipped with advanced research tools for experimental and computational studies in chemical kinetics, catalytic materials, and combustion, including quadrupole mass spectrometer (QMS) systems to sample reactive systems with electron impact and photoionization capabilities; several fully computerized gas chromatograph/mass spectrometer (GC/MS) systems for gas analysis; fully computerized array channel micro-reactors 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 work-stations for numerical investigations in fluid mechanics, detailed chemical kinetic modeling, and computational quantum chemistry.

Electrochemical Engineering and Catalysis Laboratories

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

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

Electronic Materials Processing Laboratory

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

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

Materials and Plasma Chemistry Laboratory

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

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

Nanoparticle Technology and Air Quality Engineering Laboratory

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

Concern with nanoscale phenomena requires the use of advanced systems for particle observation and manipulation. Students have direct access to modern facilities for transmission and scanning electron
Resin sorption and regeneration studies can be carried out with a fully automated system.

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

Faculty Areas of Thesis Guidance

Professors

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

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

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

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

Vijay K. Dhir, Ph.D. (U. Kentucky, 1972) Two-phase heat transfer, boiling and condensation, thermal hydraulics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling

Robert F. Hicks, Ph.D. (UC Berkeley, 1984) Chemical vapor deposition and atmospheric plasma processing


Yunfeng Lu, Ph.D. (U. New Mexico, 1998) Semiconductor manufacturing and nanotechnology

Vasilios I. Manousiouthakis, Ph.D. (Rensselaer, 1986) Process systems engineering: modeling, simulation, design, optimization, and control

Harold G. Mombouquette, Ph.D. (North Carolina State, 1987) Biochemical engineering, biosensors, nanotechnology

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

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

Professors Emeriti

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

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

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

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


Associate Processor


Assistant Professors

Yvonne Y. Chen, Ph.D. (Caltech, 2011) Synthetic biology, gene-circuit engineering, cell-based therapy, T-cell engineering

Gerassimos Orkoulas, Ph.D. (Cornell, 1998) Molecular simulation, critical phenomena in ionic fluids, thermodynamics of complex fluids

Lower Division Courses

2. Technology and Environment. (4) Lecture, four hours; outside study, eight hours. Natural and anthropogenic flows of materials at global and regional scales. Case studies of natural cycles include global warming (CO2 cycles), stratospheric ozone depletion (chlorine and ozone cycles), and global nitrogen cycles. Flow of materials in industrial economies compared and contrasted with natural flows; presentation of lifecycle methods for evaluating environmental impact of processes and products. P/NP or letter grading.

Mr. Manousiouthakis (Not offered 2013-14)

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

Mr. Liao (P)

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

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

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

100. Fundamentals of Chemical and Biomolecular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20B, 20L, Mathematics 32B (may be taken concurrently). Physics 1A. Introduction to analysis and design of chemical processes. Materials and energy balances. Introduction to programming in MATLAB. Letter grading. Mr. Manousiouthakis (FW)


101C. Mass Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101B. Introduction to analysis of mass transfer in systems of interest to chemical engineering practice. Fundamentals of mass species transport, Fick law of diffusion, analysis in chemically reacting systems, and engineering practice. Letter grading. Mr. Cohen (Sp)

102A. Thermodynamics I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to thermodynamics of chemical and biological processes. Work, energy, heat, and first law of thermodynamics. Second law, extremum principles, entropy, and free energy. Ideal and real gases, property evaluation. Thermodynamics of flow systems. Applications of first and second laws in biological processes and living organisms. Letter grading. Mr. Hicks (FW)


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

104A. Chemical and Biological Engineering Laboratory I. (4) Formerly numbered 104ALL. Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite: course 100. Corequisite: course 101B. Recommended: course 102B. Not open for credit to students with credit for former course 104ALL. Investigation of basic transport phenomena in 10 predetermined experiments, collection of data for statistical analysis and individual written technical reports and group presentations. Design and performance of one original experimental study involving transport, separation, or another aspect of chemical and biologic engineering. Basic statistical methods: mean, standard deviation, confidence limits, comparison of two means and of multiple means, single and multiple variable linear regression, and brief introduction to factorial design of experiments. Oral and poster presentations. Technical writing of sections of reports clearly, concisely, and consistently; importance of word choices and punctuation in multicultural engineering environment and of following required format. Letter grading. Mr. Grasel (W,Sp)

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

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Requisite: course 101C. Corequisite: course 104CL. Basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metallization, and statistical design of experiments and error analysis. Presentation of student results in both written and oral form. Letter grading. Mr. Hicks (Sp)

104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours; outside study, five hours. Requisite: course 101C. Corequisite: course 104C. Series of experiments that emphasize basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, and metallization. Hands-on device, wafer, masks, and equipment. Letter grading. Mr. Hicks (Sp)

104D. Molecular Biotechnology: From Gene to Product. (2) Lecture, two hours; outside study, four hours. Requisites: courses 101C, 121S. Enforced corequisite: course 104DL. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid, transformation of construct into E. coli, production of protein in E. coli, downstream processing of bioreactor broth to purify recombinant protein, and characterization of purified protein. Letter grading. Ms. Chen, Ms. Segura (F,Sp)

104DL. Molecular Biotechnology Laboratory: From Gene to Product. (2) Laboratory, two hours; outside study, four hours. Requisites: courses 101C, 121S. Enforced corequisite: course 104D. Integration of molecular and engineering techniques in modern biotechnology. Cloning of protein-coding gene into plasmid, transformation of construct into E. coli, production of protein in bioreactor, downstream processing of bioreactor broth to purify recombinant protein, and characterization of purified protein. Letter grading. Ms. Segura, Mr. Tang (F,Sp)

106. Chemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 101B. Application of stoichiometry and kinetics to analysis of chemical reactions. Chemical process control elements. Design and applications of chemical process computer control. Letter grading. Mr. Christofides (W)

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study. Requisites: courses 103 (or C125), 104A, 106 (or C115). Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering with simple economic principles for purpose of designing chemical processes and evaluating alternatives. Letter grading. Mr. Pang (W)

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour. Outside study. Requisites: courses 103 (or C125), 106 (or C115), 108A. Computer Science 31. Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading. Ms. Segura, Mr. Tang (Sp)

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Computer Science 31. Corequisite: course 101A. Numerical methods for computation of solutions of systems of linear and nonlinear algebraic equations, ordinary differential equations, and partial equations. Chemical and biomolecular engineering examples used throughout to illustrate applications of these methods. Use of MATLAB as platform (programming environment) to write programs based on numerical methods to solve various problems arising in chemical engineering. Letter grading. (Not offered 2013-14)

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

111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, Chemistry 30A. Formation of liquefied and solidified materials. Process criteria for selection of cryogenic technology. Polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering. Diffusion in polymeric systems. Polymers in biomedical applications and in microelectronics. Concurrently scheduled with course C211. Letter grading. Mr. Lu (W)

113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Requisites: courses 101C, 102B. Integrated approach to air pollution, including concentrations of atmospheric pollutants, air pollution standards, air pollution sources and sinks, and relationships of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading. (Not offered 2013-14)

114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryoengineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of refrigerants and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C212. Letter grading. Mr. Lu (W)


Chemical and Biomolecular Engineering / 41
trolysisynthesis and bioelectrochemical processes. May be concurrently scheduled with course C214. Letter grading. (Not offered 2013-14)

C115. Biochemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course CM215. Letter grading. Mr. Monbouquette (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 solid-state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of crystals and their surfaces and interfaces. Examination of engineering materials, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading.

C118. Multimedia Environmental Assessment. (4) Lecture, four hours; discussion, one hour; preparation, two hours; outside study, five hours. Requisites: courses 101C, 102B. Practical projects and computer simulations on the release, fate, and exposure assessment of chemical pollutants in environment, including atmospheric, aquatic, and soil systems. Topics include biota, ecosystems, mathematical models, and multimedia modeling of chemical partitioning in environment. Letter grading. Mr. Lu (Sp)


C121, Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, consequence of processes at atomistic and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of membranes for desalination and catalytic membranes and models of membrane transport (flux and selectivity). Examples provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C221. Letter grading. Mr. Cohen (Not offered 2013-14)

C124. Cell Material Interactions. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 2, 3, 23L. Introduction to design and synthesis of biomaterials for regenerative medicine in vivo and cell culture, and drug delivery. Biological principles of cellular microenvironment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor sites, cell and mRNA delivery, as therapeutic and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224. Letter grading. (Not offered 2013-14)

C125. Bioseparations and Bioprocess Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Corequisite: course 101C. 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. Tang (Sp)

CM127. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM127.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 153A, Life Sciences 3, 23L. Engineering of biocomponents is a common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. The understanding of metabolic pathways, pathways of primary metabolism, genetic manipulation of host organisms, and control of metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM227. Letter grading. (Not offered 2013-14)

C135. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 107. Introduction to advanced process control. Topics include (1) Lyapunov stability for autonomous nonlinear systems including converse theorems, (2) input to state stability, interconnected systems, and small gain theorems, (3) design of nonlinear and robust controllers for various classes of nonlinear systems, (4) predictive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of distributed parameter systems. Concurrently scheduled with course C235. Letter grading. Mr. Christofides (Sp)

C140. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Technology of particle/gas systems with applications to gas cleaning, commercial production of fine particles, and catalysis. Particle transport and deposition, optical properties, experimental methods, control of particle and formation processes. Concurrently scheduled with course C240. Letter grading. (Not offered 2013-14)

CM145. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 3, 23L. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading. Ms. Chen (F)

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

Mr. Senkan (Not offered 2013-14)

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

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

Ms. Yang (F,Sp)

Graduate Courses

200. Advanced Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 102B, Phenomenological and statistical thermodynamics of chemical and physical systems with engineering applications. Presentation of role of atomic and molecular systems and intermolecular forces in interpretation of thermodynamic properties of gases, liquids, solids, and plasmas. Letter grading.

Mr. Orkoulas (F)

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 200 or Chemistry 223A or Physics 215A. Modern simulation techniques for classical molecular systems including Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading.


Mr. Manousiouthakis (W)

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 102A, 110A (or Materials Science 130). Fundamentals of cryogenics and cryogenics engineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes necessary for operation of cryogenic equipment. Cryogenics—temperature behavior of material, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading.

Mr. Yuan (F)

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

C214. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Present emphasis on fundamentals of corrosion, analysis of corrosion and prevention processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal and semiconductor surface finishing, passivity, electrodeposition, electrolysis, synthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. (Not offered 2013-14)

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

C216. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: Chemistry 113A. Introduction to surfaces and interfaces of engineering materials, particularly catalytic surface and thin films for solid-state electronic devices. Topics include classification of crystals and surfaces, and physical properties and composition of crystals and their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelec-
217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical systems; relationships between molecular transport, conduction and reaction kinetics, along with applications to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading.

Mr. Nobe (Not offered 2013-14)


Ms. Segura (W)

CM225. Bioseparations and Bioprocessing Engineering. (4) (Same as Biomedical Engineering M225) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 101C. Separation strategies, unit operations, and effective factors used to design processes for isolating and purifying molecules like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently scheduled with course C125. Letter grading.

CM227. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM227.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 13SA, Life Sciences 3, 23L. Engineering microorganisms for complex phenotypes is a common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves designing novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, protein structure, and biological regulation and are aided by tools in bioinformatics, systems biology, and synthetic biology. Fundamentals of metabolic engineering, protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM127. S/U or letter grading. (Not offered 2013-14)


Mr. Serkan

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. Serkan

233. Frontiers in Biotechnology. (2) Formerly numbered 240. Lecture, one hour. Requisite: Life Sciences 3. Integration of science and business in biotechnology. Academic research leading to licensing and founding of companies that turn research breakthroughs into marketable products. Invited lecturers from academia and industry cover emerging areas of biotechnology from combination of science, engineering, and business points of view. S/U or letter grading. (W)

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

Ms. Chang, Mr. Hicks

C235. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 107. Introduction to advanced process control. Topics include (1) Lyapunov stability for autonomous nonlinear systems including converse theorems, (2) input to state stability, interconnected systems, and small gain theorems, (3) design of nonlinear and robust controllers for various classes of nonlinear systems, (4) model predictive control of linear and nonlinear systems, (5) advanced methods for tuning of classical controllers, and (6) introduction to control of parameter uncertain systems. Concurrently scheduled with course C135. Letter grading.

Mr. Chofstides (Sp)

236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 210, 216. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic devices. Topics include reactor design, transport phenomena, gas and surface chemical kinetics, structure and composition, deposition mechanisms, and relationship between process conditions and film properties. Letter grading.

Mr. Hicks

240. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Technology of particle/gas systems with applications to gas cleaning, commercial production of fine particles, and catalysis. Particle transport and deposition, optical and experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C140. Letter grading. (Not offered 2013-14)

CM245. Molecular Biotechnology for Engineers. (4) (Same as Biotechnology CM245) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Life Sciences 3, 23L. Selected topics in molecular biology that form foundation of biotechnology and biomedical engineering processes. Include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and therapeutics, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading.

Ms. Chen (F)


Mr. Liao

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

Mr. Manoussikhakis

polymeric liquids and dispersed systems. Applications in viscometry, polymer processing, bioreology, oil recovery, and drag reduction. Letter grading.

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

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

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

M280C. Optimal Control. (4) (Same as Electrical Engineering M240C and Mechanical and Aerospace Engineering M270C) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 240B or Mechanical and Aerospace Engineering 270B. Applications of variational methods, Pontryagin maximum principle, Hamilton/Jacobi/Bellman equation (dynamical programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading.


283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M230A, M232A. Designed for graduate students. Introduction to advanced dynamical analysis and controller synthesis methods for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Banach and Hilbert spaces, semigroup theory, convergence theory in function spaces), (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition), (3) nonlinear and robust control of nonlinear hyperbolic and parabolic partial differential equations (PDEs), (4) applications to transport-reaction processes. Letter grading.

Mr. Christofides


Mr. Manousiouthakis

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

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

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

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

495A. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, four hours; one-day intensive training at beginning of Fall Quarter. Limited to graduate chemical engineering students. Requisites: courses M280A, M282A. Designed for teaching assistants interested in learning more about effective use of technology and ways to incorporate that technology into their classrooms for benefit of student learning. S/U grading. (F,W,Sp)

495B. Teaching with Technology for Teaching Assistants. (2) Seminar, two hours; outside study, four hours. Limited to graduate chemical engineering students. Designed for teaching assistants interested in expanding technology use in teaching. S/U grading.

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

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

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

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

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

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Professors
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Eric M.V. Hoek, Ph.D.
Jiann-Wen (Woody) Ju, Ph.D.
Steven A. Margulis, Ph.D.
Michael K. Stenstrom, Ph.D.
Jonathan P. Stewart, Ph.D.
Keith D. Stoltenbach, Ph.D.
Ertugrul Tacioglu, Ph.D.
Mladen Vucetic, Ph.D.
John W. Wallace, Ph.D.
William W-G. Yeh, Ph.D. (Richard G. Newman AECOM Endowed Professor of Civil Engineering)

Professors Emeriti
Stanley B. Dong, Ph.D.
Lewis P. Felton, Ph.D.
Michael E. Fournier, Ph.D.
Gary C. Hart, Ph.D.
Poul V. Lade, Ph.D.
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
Scott J. Brandenberg, Ph.D.
Mekonnen Gebremichael, Ph.D.
Jennifer A. Jay, Ph.D.
Jian Zhang, Ph.D.

Assistant Professors
Shalily Mahendra, Ph.D.
Gaurav Sant, Ph.D. (Edward K. and Linda L. Rice Endowed Professor of Materials Science)

Adjunct Professors
Robert E. Kayen, Ph.D.
Thomas Sabol, Ph.D.
Ne-Zheng Sun, Ph.D.

Adjunct Associate Professors
Terri S. Hogue, Ph.D.
Donald R. Kendall, Ph.D.
Issam Najm, Ph.D.
Daniel E. Pradel, Ph.D.

Scope and Objectives

The civil and environmental engineering programs at UCLA include civil engineering materials, earthquake engineering, environmental, and structural engineering, geotechnical engineering, hydology and water resources engineering, structural engineering, and structural mechanics.

The civil engineering undergraduate curriculum leads to a B.S. in Civil Engineering, a broad-based education in environmental engineering, geotechnical engineering, hydrology and water resources engineering, and structural engineering and mechanics. This program is an excellent foundation for entry into professional practice in civil engineering or for further advanced study. The department also offers the undergraduate Environmental Engineering minor.

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

Department Mission

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

Undergraduate Program Objectives

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

Undergraduate Study

The Civil Engineering major is a designated capstone major. In each of the major field design courses, students work individually and in groups to complete design projects. To do so, they draw on their prior coursework, research the needed materials and possible approaches to creating their device or system, and come up with creative solutions. This process enables them to integrate many of the principles they have learned previously and apply them to real systems. In completing their projects, students are also expected to demonstrate effective oral and written communication skills, as well as their ability to work productively with others as part of a team.

Civil Engineering B.S.

Capstone Major

Preparation for the Major

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

The Major

Required: Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A; Civil and Environmental Engineering 101, 103, 108, 110, 120, 135A, 150, 153, Materials Science and Engineering 104, Mechanical and Aerospace Engineering 103, 182A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and at least nine major field elective courses (36 units) that must include the required courses in two of the following tracks and at least two laboratory courses, one of which must be from one of the two selected tracks and the other from any separate track or from the list of additional elective laboratory options:

Environmental Engineering: Required: One capstone design course from Civil and Envi-
Environmental Engineering Minor

The Environmental Engineering minor is designed for students who wish to augment their major program of study with courses addressing issues central to the application of environmental engineering to important environmental problems facing modern society in developed and developing countries. The minor provides students with a greater depth of experience and understanding of the role that environmental engineering can play in dealing with environmental issues. To enter the minor, students must be in good academic standing (2.0 grade-point average or better) and file a petition in the Office of Academic and Student Affairs, 6426 Boelter Hall.

Required Lower Division Course (4 units):
Mathematics 3C or 32A.

Required Upper Division Courses (24 units minimum):
Civil and Environmental Engineering 153 and five courses from 151, 154, 155, 156A, M168, Chemical Engineering C118, Environmental Health Sciences C125, C164.

A minimum of 20 units applied toward the minor requirements must be in addition to units applied toward major requirements or another minor, and at least 16 units applied toward the minor must be taken in residence at UCLA. Transfer credit for any of the above is subject to departmental approval; consult the undergraduate counselors before enrolling in any courses for the minor.

Each minor course must be taken for a letter grade, and students must have a minimum grade of C (2.0) in each and an overall grade-point average of 2.0 or better. Successful completion of the minor is indicated on the transcript and diploma.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the detailed degree requirements as published in Program Requirements for the year in which they enter the program.

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

Civil Engineering M.S.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses are required, a majority of which must be in the Civil and Environmental Engineering Department. At least five of the courses must be at the 200 level. In the thesis plan, seven of the nine must be formal 100- or 200-series courses. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, 500-series courses may not be applied toward the nine-course requirement. A minimum 3.0 grade-point average is required in all coursework.

Each major field has a set of required preparatory courses which are normally completed during undergraduate studies. Equivalent courses taken at other institutions can satisfy the preparatory course requirements. The preparatory courses cannot be used to satisfy course requirements for the M.S. degree; courses must be selected in accordance with the lists of required graduate and elective courses for each major field.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101A, 102, 103, 110L, M168, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

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

Civil Engineering Materials

Required Preparatory Courses. General chemistry and physics with laboratory exercises, multivariate calculus, linear algebra, and differential equations, introductory thermodynamics. Other undergraduate preparation could include Civil and Environmental Engineering C104, 120, 121, 135A, 140L, 142, and Materials Science and Engineering 104.

Required Graduate Courses. Two courses must be selected from Civil and Environmental Engineering C204, 226, 253, 258A, 261B, M262A, 263A, 266, 267.


Environmental Engineering

Required Preparatory Courses. Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 153; Mathemat-
ics 32A, 33A; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 4AL, 4BL.

**Required Graduate Courses.** Civil and Environmental Engineering 254A, 255A, 255B, 266.


**Geotechnical Engineering**

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

**Required Graduate Courses.** Civil and Environmental Engineering 220, 221, 223, 224.

**Major Field Elective Courses.** Minimum of three courses must be selected from Civil and Environmental Engineering 123, 128L, 222, 225, 226, 227, 245.


**Hydrology and Water Resources Engineering**

**Required Preparatory Courses.** Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering 151, 153; Mathematics 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 103, 105A; Physics 1A, 1B, 1C, 4AL, 4BL.

**Required Graduate Courses.** Civil and Environmental Engineering 250A through 250D.

**Major Elective Courses.** Minimum of three courses must be selected from Civil and Environmental Engineering 251A through 251D, 252, 253, 260.

**Additional Elective Courses.** For students in the thesis plan, a maximum of two of the following courses: Civil and Environmental Engineering 110, 150, 153, 157L, 157M, 164, 254A, 255A, 255B, 263A, 265A, 265B; for students in the comprehensive examination plan, up to two courses from the following subject areas: atmospheric and oceanic sciences, computer science, electrical engineering, geography, mathematics, and statistics.

**Structural/Earthquake Engineering**

**Required Preparatory Courses.** Civil and Environmental Engineering 135A, 135B, and 141 (or 142).

**Required Graduate Courses.** Civil and Environmental Engineering 235A, 246, and at least three courses from 235B, 241, 243A, 245, 247.

**Elective Courses.** Undergraduate—no more than two courses from Civil and Environmental Engineering 125, M135C, 137, 143, and either 141 or 142; geotechnical area—Civil and Environmental Engineering 220, 221, 222, 223, 225, 227; general graduate—Civil and Environmental Engineering M230A.

Professor Eric M.V. Hoek leads a team of UCLA graduate students to nine remote villages in Fiji to assess and design safe water and sanitation plans for 8,000 people and dozens of schools. The UCLA team works with Global Classrooms for Peace to improve public health in rural Fiji by providing clean safe drinking water.
Civil Engineering Ph.D.

Major Fields or Subdisciplines

Civil engineering materials, 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 selected 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 in the department. The outside member must be a UCLA faculty member in another department.

Fields of Study

Civil Engineering Materials

Ongoing research is focused on inorganic, random porous materials and incorporates expertise at the interface of chemistry and materials science to develop the next generation of sustainable construction materials. The work incorporates aspects of first principles and continuum scale simulations and integrated experiments, ranging from nano- to macro scales. Special efforts are devoted toward developing low-clinker factor cements and concretes, reducing the carbon footprint of construction materials, and increasing the service life of civil engineering infrastructure.

Environmental Engineering

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

Geotechnical Engineering

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

Hydrology and Water Resources Engineering

Ongoing research in hydrology and water resources deals with surface and groundwater processes, hydrometeorology and hydroclimatology, watershed response to disturbance, remote sensing, data assimilation, hydrologic modeling and parameter estimation, multiobjective resources planning and management, numerical modeling of solute transport in groundwater, and optimization of conjunctive use of surface water and groundwater.

Structures (Structural Mechanics and Earthquake Engineering)

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

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

Teaching and research areas in structural/earthquake engineering involve assessing the performance of new and existing structures subjected to earthquake ground motions. Specific interests include assessing the behavior of reinforced concrete buildings and bridges, as well as structural steel, masonry, and timber structures. Integration of analytical studies with laboratory and field experiments is emphasized to assist in the development of robust analysis and design methods.

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

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

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

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

Hydrology Laboratory
The Hydrology Laboratory is used for studying basic surface water processes and characterizing a range of geochemical parameters. Basic experiments include measurements of suspended solids, turbidity, dissolved oxygen, sediment distributions, and other basic water quality constituents. The laboratory also includes an extensive suite of equipment for measuring surface water processes in situ, including precipitation, stage height, discharge, channel geomorphology, and other physical parameters.

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

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

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

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

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

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

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

Experimental Mechanics Laboratory
The Experimental Mechanics Laboratory supports two major activities: the Optical Metrology Laboratory and the Experimental Fracture Mechanics Laboratory. In the Optical Metrology Laboratory, tools of modern optics are applied to engineering problems. Such techniques as holography, speckle-interferometry, Moiré analysis, and fluorescence-photo mechanics are used for obtaining displacement, stress, strain, or velocity fields in either solids or liquids. Recently, real-time video digital processors have been combined with these modern optical technical techniques, allowing direct interfacing with computer-based systems such as computer-aided testing or robotic manufacturing.
The Experimental Fracture Mechanics Laboratory is currently involved in computer-aided testing (CAT) of the fatigue fracture mechanics of ductile material. An online dedicated computer controls the experiment as well as records and manipulates data.

Large-Scale Structure Test Facility

The Large-Scale Structure Test Facility allows investigation of the behavior of large-scale structural components and systems subjected to gravity and earthquake loadings. The facility consists of a high-bay area with a 20 ft. x 50 ft. strong floor with anchor points at 3 ft. on center. Actuators with servo-hydraulic 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 electro-thermal loadings.

Soil Mechanics Laboratory

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

Faculty Areas of Thesis Guidance

Professors

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

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

Jason-Wen (Woody) Ju, Ph.D. (UC Berkeley, 1986)
Dissipative mechanics, mechanics of composite materials, computational plasticity, micromechanics, concrete modeling and durability, computational mechanics

Steven A. Margulis, Ph.D. (MIT, 2002)
Surface hydrology, hydrometeorology, remote sensing, data assimilation

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

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

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

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

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

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

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 analysis, 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. (Caltech, 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

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

Chung Yen Liu, Ph.D. (Caltech, 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

Moste F. Rubinstein, Ph.D. (UCLA, 1961)
Systems analysis and design, 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. Selma, Ph.D. (UC Berkeley, 1967)
Reinforced concrete, earthquake engineering

Associate Professors

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

Mekonnen Gebremichael, Ph.D. (U. Iowa, 2004)
Remote sensing of hydrology, watershed hydrologic modeling, hydro meteorology, stochastic hydrologic analysis

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

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

Assistant Professors

Shailly Mahendra, Ph.D. (UC Berkeley, 2007)
Environmental microbiology, biodegradation of groundwater contaminants, microbial-nanomaterial interactions, applications of molecular biological and isotopic tools in environmental engineering

Gaurav Sant, Ph.D. (Purdue, 2009)
Cementitious materials and porous media with focus on chemistry-microstructure-property relationships, geochemical modeling, shrinkage and cracking, thermodynamics of interfaces, durability prediction and extension, and carbon footprint minimization of construction materials

Adjunct Professors

Robert E. Kayen, Ph.D. (UC Berkeley, 1993)
Geometrics and terrestrial laser-topographic modeling, geotechnical earthquake engineering, engineering geology, applied geophysics

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

Jonathan P. Stewart, Ph.D. (UC Berkeley, 1996)
Geotechnical engineering, earthquake engineering, experimental mechanics, special emphasis on application of modern optical techniques

David R. Kendall, Ph.D. (UCLA, 1989)
Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes

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

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

Lower Division Courses

1. Introduction to Civil Engineering. (2) Lecture, two hours; outside study, four hours. Introduction to scope of civil engineering profession, including earthquake, environmental, coastal, architectural, transportation, and water resources engineering. P/NP grading. Mr. Stewart (F)

15. Introduction to Computing for Civil Engineers. (2) Lecture, two hours; laboratory, two hours; outside study, two hours. Introduction to computer programming using MATLAB. Selected topics in programming, with emphasis on numerical techniques and methodology as applied to civil engineering programs. Letter grading. Mr. Chen, Mr. Margulis (FW)

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

58SL Climate Change, Water Quality, and Ecosystem Functioning. (5) Lecture, four hours; service learning, two hours; outside study, nine hours. Science related to climate change, water quality, and ecosystem health. Topics include carbon and nutrient cycling, hydrologic cycle, ecosystem structure and services, biodiversity, basic aquatic chemistry, and impacts of climate change on ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading. Ms. Jay (Sp)
85. Professional Practice Issues in Structural En-
gineering. (2) Seminar, two hours; outside study, four hours. Problems and solutions to issues of professional practice in structural engineering. Content and organization of model building codes and material-specific reference standards. Interpretation of architectural and struc-
tural design drawings and specifications. Materials test-
dependent structural calculations such as tributary area, multi-story column loads, and estimation of sim-
ple seismic and wind loads. P/NP grading. (Formerly num-
bered 129.) Lecture, two hours; recitation, two hours; labora-

97. Variable Topics in Civil and Environmental En-
gineering. (2 to 4) Seminar, two hours. Current topics and research methods in civil and environ-
mental engineering. May be repeated for credit. 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-
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 Under-
graduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

101. Statics and Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requi-
sites: Mathematics 31A, 31B, Physics 1A. Newton-
ian mechanics, vector representation, and resultant forces and moments. Free-body diagrams and equi-
librium of particles. Kinematics. Linear and nonlinear systems, distributed forces, determinant and indeterminate force systems, shears and moment diagrams, and ax-
ial force diagrams. Course concludes with introduction to strain energy and rigid body mechanics. Linear and angular momentum and impulse. Multi-
particle systems. Kinematics and kinetics of rigid bodies in two- and three-dimensional motions. Letter grading.

103. Applied Numerical Computing and Modeling in Civil and Environmental Engineering. (4) 
Lecture, four hours; discussion, two hours; outside study, six hours. Requi-
manufacture of cement and production of concrete. Aspects of cement composition and basic chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control. Stress-strain testing. Development and testing of fundamentals for complete understanding of overall response of all civil engineering materials. By end of term, successful utilization of fundamental 
materials science concepts to understand, explain, analyze, and describe engineering performance of 
civil engineering materials. Concurrently scheduled with course C104. Letter grading.

105. Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Techniques for 
effectively communicating technical material accurately, 
clearly, and briefly, with emphasis on writing and development of oral presentation skills. How to write clearly and concisely, organize material logically, present it in readable style, edit work accurately, and apply sound writing principles to technical docu-
ments. Topics include organization of information; ap-
lication of techniques to achieve unity, coherence, 
and development; use of parallel grammatical struc-
ture effectively; avoidance of common writing errors; and structuring and defining paragraphs. Letter grading. Ms. Shane (Not offered 2013-14)

106A. Problem Solving in Engineering Economy. (4) Lecture, four hours; outside study, eight hours. Designed for juniors/seniors. Problem-solving and decision-making framework for design of engineering projects. Foundation for understanding corporate financial practices and accounting. Deci-
sions on capital investments and choice of alterna-
tives for engineering applications in all fields. Intro-
duction to use of engineering economics in analysis of infla-
tion and public investments. Letter grading.

109. Introduction to Mechanics of Deformable 
Solids. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathe-
matics 33A, Physics 1A. Corequisite: course 101. Re-
view of equilibrium principles; forces and moments trans-
mitted by slender members. Concepts of stress and strain. Stress-strain relations with focus on linear 
elasticity. Transformation of stress and strain. Defor-
mations and stresses caused by tension, compres-
sion, bending, and shear. Reaction mem-
bers. Structural applications to trusses, beams, shafts, and columns. Introduction to virtual work prin-
ciple. Letter grading. Mr. Stewart (W)

110. Introduction to Probability and Behav-
ior for Engineers. (4) Lecture, four hours; discussion, one hour (when scheduled); outside study, seven hours. Requisites: Mathematics 32A, 33A. Recommended: course 15. Introduction to fundamental concepts and applications of probability and statistics in civil engi-
neering, 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 con-
cepts, random variables and analytical probability distributions, functions of random variables, estimat-
ing parameters from observed data, regression, hypothesis testing, and Bayesian concepts. Letter grading.

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

121. Design of Foundations and Earth Structures. (4) Lecture, four hours; discussion, two hours; 
outside study, six hours. Requisite: course 120. Design and construction of foundations and earth 
structures; virtual work; analysis of indeterminate struc-
tures; stability of slopes and retaining structures. Letter grading. Mr. Stewart (W)

123. Advanced Geotechnical Design. (4) 
Lecture, four hours; computer laboratory; two hours; outside study, six hours. Requisite: course 121. Analysis and design of earth dams, including seepage, piping, and slope stability analyses. Case history studies involv-
ing landslides, settlement, and expansive soil prob-
lems. Design methods for slope stability purposes. Site in-
vestigation, including evaluation of soil properties for design. Design of footings and piers, including stabili-
ty and settlement calculations. Design of slopes and earth retaining structures. Letter grading. Mr. Vucetic (F)


128L. Soil Mechanics Laboratory. (4) Lecture, one 
hour; laboratory, eight hours; outside study, three hours. Requisite or corequisite: course 120. Labora-
tory experiments to be performed by students to ob-
tain soil parameters required for analysis of site problems. Soil classification, grain size distribution, Atterberg limits, specific gravity, compaction, expansion index, consolidation, shear strength determina-
tion. Design problems, laboratory report writing. Let-
ter grading. Mr. Brandenberg, Mr. Vucetic (F)

129L. Engineering Geomatics. (4) Formerly num-
bered 129.) Lecture, two hours; recitation, two hours; labora-
atory, four hours; outside study, four hours. Col-
lection, processing, and analysis of geospatial data. Ellipsoid and geoid models of shape of Earth. Sea level, height, and geopotential surfaces. Elements and usage of topographic data and maps. Advanced global positioning systems (GPS) for high precision mapping. Advanced laser-based light detection and ranging (LIDAR) mapping. Quantitative terrain analy-
sis and change detection. Hydrogeometrics; seafloor mapping. Letter grading. Mr. Vucetic (W)

130. Elementary Structural Mechanics. (4) 
Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 108. Analysis of structures in two- and three-dimensional motions. Letter grading. Ms. Zhang (F/W)

130L. Experimental Structural Mechanics. (4) 
Lecture, two hours; laboratory, six hours; outside study, four hours. Requisite or corequisite: course 130. 
Lecture and laboratory program to study fundamentals of structural mechanics testing of metals, plastics, and concrete. Direct tension. Direct compression. Ultrasonic non-
destructive evaluation. Elastic buckling of columns. Fracture mechanics testing and fracture toughness. Splitting and flexural tension. Elastic, plastic, and frac-
ture behavior. ASTM, RILEM, and USBR. Cyclic 
loading. Microstructures of concrete. Size effects. Letter grading. Mr. Taciorgul, Mr. Wallace (W)

135A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 15, 103, 108. Introduction to structural analysis; classification of structural ele-
ments; analysis of statically determinate trusses, beams, and frames; deflections in elementary struc-
tures; virtual work; analysis of indeterminate struc-
tures using force method; introduction to displacemen-
t method and energy method. Letter grading. Ms. Zhang (F/W)

135B. Intermediate Structural Analysis. (4) 
Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Analysis of truss and frame structures using matrix methods; matrix force methods; matrix displacement method; analy-
sis concepts based on theorem of virtual work; mo-
ment distribution. Letter grading. Ms. Zhang (F/W)

M135C. Introduction to Finite Element Methods. (4) (Same as Mechanical and Aerospace Engineering M168L.) Lecture, four hours; discussion; one hour; outside study, seven hours. Requisite: course 130 or Mechanical and Aerospace Engineering 156A or 166A. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and composites. Direct and matrix 
structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; 
convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postpro-
cessing techniques; term projects with computers. Letter grading. Mr. Chen, Mr. Klug (F)

Civil and Environmental Engineering / 51
135L. Structural Design and Testing Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Prerequisites: courses 135B, 135A. Limited enrollment. Computer-aided optimum design, construction, instrumentation, and test of small-scale model structure. Use of computer-based data acquisition and interpretation systems for comparison of experimental and theoretically predicted behavior. Letter grading. Mr. Wallace (Sp).

144. Structural Systems Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 141 or 142. Design course for civil engineering students, with focus on design and construction of building structural systems. International Building Code (IBC) and ASCE 7 dead, live, wind, and earthquake loads. Design of reinforced concrete and structural steel buildings. Computer modeling, analysis, and performance assessment of buildings. Letter grading. Mr. Wallace (Sp).


150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 15, Mechanical and Aerospace Engineering 103. Study of hydrologic cycle and relevant atmospheric processes, water balance, precipitation, evaporation, infiltration, evapotranspiration, groundwater flow, storm runoff, and flood processes. Letter grading. Mr. Margulis (F).

151. Design and Construction of Water Resource Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 150, Mechanical and Aerospace Engineering 103. Recommended: courses 103, 110. Principles of hydraulics, flow of water in open channels and pressure conduits, reservoirs and dams, hydraulic machinery, hydroelectric power. Introduction to system analysis and design applied to water resources engineering. Letter grading. Mr. Margulis (W).

153. Introduction to Environmental Engineering Science. (4) Lecture, four hours; discussion, one hour (when scheduled); outside study, seven hours. Recommended requisite: Mechanical and Aerospace Engineering 103. Water, air, and soil pollution: sources, transformations, effects, and processes for removal of contaminants. Water quality, water and wastewater treatment plants, hydraulic and environmental models. Letter grading. Mr. Stenstrom (Sp).

154. Chemical Fate and Transport in Aquatic Environments. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 150, Mechanical and Aerospace Engineering 103. Recommended: courses 103, 110. Prerequisites: hydrologic and chemical processes in snow-dominated and mountainous regions. Students measure and quantify snowpack properties, snowmelt, discharge, evaporation, infiltration, soil properties, and local meteorology, as well as investigate geochemical properties of surface and groundwater systems. Exploration of rating curves, stream classification, and flooding potential. Extended field trip required. Letter grading. Mr. Margulis (Not offered 2013-14).

155. Unit Operations and Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 153. Fundamental physical, chemical, and biological principles governing movement and fate of chemicals in surface waters and groundwater. Topics include physical transport in various aquatic environments, air-water exchange, acid-base equilibria, oxidation-reduction chemistry, chemical sorption, biodegradation, and bioaccumulation. Practical quantitative problems solved considering both reaction and transport of chemicals in environment. Letter grading. Ms. Jay (Sp).

156. Environmental Engineering Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, six hours. Requisite: courses 150, 157L. Advanced field laboratory course focusing on design study of hydrologic and geochemical processes in snow-dominanted and mountainous regions. Students measure and quantify snowpack properties, snowmelt, discharge, evaporation, infiltration, soil properties, and local meteorology, as well as investigate geochemical properties of surface and groundwater systems. Exploration of rating curves, stream classification, and flooding potential. Extended field trip required. Letter grading. Mr. Margulis (Not offered 2013-14).

164. Hazardous Waste Site Investigation and Remediation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150, 153, Mechanical and Aerospace Engineering 103. Waste disposal and reaction, decomposition/deposition of acid precipitation, fate of anthropogenic/toxic/natural organic and inorganic compounds, selected global chemical cycle(s). Control technologies. Letter grading. Mr. Stolzenbach (Not offered 2013-14).

157. Design of Water Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Requisite: course 155. Design process of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and cost estimation. Letter grading. Mr. Stenstrom (Not offered 2013-14).

157L. Hydrologic Analysis. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisite: course 150, Collection, compilation, and interpretation of data for quantification of components of hydrologic cycle, including precipitation, evaporation, infiltration, and runoff. Use of hydrologic variables and parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Letter grading. Mr. Margulis (W).

157M. Hydrology of Mountain Watersheds. (4) Lecture, one hour; fieldwork, four hours; laboratory, three hours; outside study, four hours; one field trip. Requisite: courses 150 or 157L. Advanced field laboratory course focusing on study of hydrologic and geochemical processes in snow-dominanted and mountainous regions. Students measure and quantify snowpack properties, snowmelt, discharge, evaporation, infiltration, soil properties, and local meteorology, as well as investigate geochemical properties of surface and groundwater systems. Exploration of rating curves, stream classification, and flooding potential. Extended field trip required. Letter grading. Mr. Margulis (Not offered 2013-14).

M165. Environmental Nanotechnology: Implications and Applications. (4) Same as Engineering M103S. Lecture, four hours; discussion, two hours; outisde study, six hours. Recommended requisite: course 153. Microbially cell and its metabolic capabilities, microbial genitic and functional diversity. A detailed discussion of the fundamentals of growth, microbial ecology and diversity, microbiology of wastewater treatment, probing of microbes, public health microbiology, pathogen control. Mr. Brandenberg (F).

M166L. Environmental Microbiology and Biotechnology Laboratory. (1) Same as Environmental Health Sciences M166L. Laboratory, two hours; outside study, two hours. Corequisite: course M166. General laboratory techniques in 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.

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 paving materials. Mr. Brandenberg (F).

181. Traffic Engineering Systems: Operations and Control. (4) Lecture, four hours; fieldwork/laboratory, two hours; outside study, six hours. Designed for juniors/seniors. Applications of traffic flow theories; data collection, analysis, signal control, intersection capacity analyses; simulation models; traffic signal design; signal timing design, implementation, and performance evaluation; intelligent Transportation Systems concept, architecture, and integration. Letter grading. Mr. Brandenberg (Not offered 2013-14)

C182. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses C104, 108, 120, Materials Science 104. Correlation, analysis, and interpretation of aspects of pavement design, including materials selection and traffic loading and volume. Special attention to aspects of pavement distress/serviceability and factoring of these into metrics of pavement performance. Discussion of potential choices for pavement treatments (i.e., asphalt and concrete) and their specific strengths and weaknesses in paving applications. Unification and correlation of different variables that influence pavement performance and load-bearing capacity of pavement layers. Mr. Vucetic (F).

188. Special Courses in Civil and Environmental Engineering. (2 to 6) Lecture, to be arranged; outside study, six hours. Special topics in civil engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

192. Undergraduate Practicum in Civil and Environmental Engineering. (4) Laboratory, four hours; activity, four hours; outside study, four hours. Preparation: completion of high school-focused California Teaching Associate Program. Recommended co-requisite: undergraduate research project directed at secondary school teaching career. Development of pedagogical assignments. Students assist with relevant readings and discussions and pedagogical literature, experimentation with existing and new laboratory procedures and equipment, mini-lectures and demonstrations to enrolled course students, and implementation of innovative teaching techniques. Stu-
dents gain experience in relevant laboratory-based engineering courses and obtain hands-on course development experience under guidance of faculty members. Letter grading.

194. Research Group Seminars: Civil and Environmental Engineering. (2 to 8) Seminar, two to eight hours; outside study, four to 16 hours. Designed for undergraduate students who are part of research groups. Discussion of research methods and current literature in field or of research of faculty members or students. May be repeated for credit. Letter grading.

199. Directed Research in Civil and Environmental Engineering. (2 to 12) Seminar, two to eight hours; limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culumnating paper or project required. May be repeated for credit with school approval. Individual contract required. M5 and M6 available in Office of Academic and Student Affairs. Letter grading.

Graduate Courses

C204. Structure, Processing, and Properties of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Discussion of aspects of cement and concrete materials, including manufacture of cement and production of concrete. Aspects of cement composition and basic chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control and acceptance testing. Development and testing of fundamentals for complete understanding of overall response of all civil engineering materials. By end of term, successful utilization of fundamental materials science concepts to understand, explain, analyze, and describe engineering performance of civil engineering materials. Concurrently scheduled with course C194. Letter grading. Mr. Sant (W)


221. Advanced Foundation Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 121, 220. Basic stress analysis; bearing capacity and settlement of shallow foundations, including spread footings and mats. Performance of driven piles and drilled shaft foundations under vertical and lateral loading. Construction considerations. Letter grading. Mr. Brandenberg (W)

222. Introduction to Soil Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Review of engineering problems involving soil dynamics. Fundamentals of theoretical soil dynamics: response of sliding block-on-plane to cyclic earthquake loads, application of theories of single and multiple DOF to earthquake effects on earth-quake ground motions. Soil-structure interaction, including inertial and kinematic interaction and foundation deformations under seismic loading. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

224. Advanced Soil Mechanics Laboratory. (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisites: courses 120, 121. Lecture 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 (Not offered 2013-14)

M230A. Linear Elasticity I. (4) Same as Mechanical and Aerospace Engineering M256A.) 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 models concerns such as stress redistribution, nonlinearity, existence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of computer modeling of soils using finite element method, and to constitutive modeling based on elasticity and plasticity theories. Special emphasis on numerical applications and identification of models concerns such as stress redistribution, nonlinearity, existence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Not offered 2013-14)

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 (Not offered 2013-14)

M230A. Linear Elasticity I. (4) Same as Mechanical and Aerospace Engineering M256A.) 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 models concerns such as stress redistribution, nonlinearity, existence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

229. Linear Elasticity II. (4) Same as Mechanical and Aerospace Engineering M256B.) 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 models concerns such as stress redistribution, nonlinearity, existence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

4. Lecture, four hours; outside study, eight hours. Requisite: course 130. 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.

Ms. Zhang (F)


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 analyses 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. Requisite: courses 243A, 246. Information on response and behavior of reinforced concrete structures. Structural behavior of seismic systems, including structural and nonstructural elements. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, and ductility in design, use of prescriptive versus performance-based design of buildings. Letter grading. Mr. Wallace (W)

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

245. Earthquake Ground Motion Characterization. (4) Lecture, four hours; outside study, eight hours. Corequisite: course 137 or 246. Earthquake fundamental systems, plate tectonics, fault types, seismic waves, and magnitude scales. Characterization of earthquake source, including magnitude range and rate of future earthquakes. Ground motion prediction equations and site effects on ground motion. Seismic hazard analysis. Ground motion selection and modification for response history analysis. Letter grading. Mr. Stewert (W)

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

250A. Surface Water Hydrology. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 150, 250B. In-depth study of surface water hydrology, including discussion and interrelationship of major topics such as rainfall and evaporation, soils and infiltration properties, runoff and snowmelt processes. Introduction to rainfall-runoff modeling, floods, and policy issues involved in water resource engineering and management. Letter grading. Mr. Margulis (F)


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

250D. Water Resources Systems Engineering. (4) 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 resource projects; and multiobjective planning and conjunctive use of surface and groundwater. Emphasis on management of water quantity. Letter grading. Mr. Yeh (W)

251A. Rainfall-Runoff Modeling. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250B. Introduction to modeling concepts, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed mod-
25A. Membrane Separations in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Description 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 standpoint. Letter grading. Mr. Hoek (Not offered 2013-14)

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

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

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

261. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 254A, 255A. Colloidal interactions, colloidal stability, colloidal hydrodynamics, surface chemistry, adsorption of pollutants on colloidal surfaces, transport of colloids in porous media, coagulation, and particle deposition. Consideration of applications to colloidal processes in aquatic environments. Letter grading. Mr. Hoek (Not offered 2013-14)

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

M252A. Introduction to Atmospheric Chemistry. (4) (Same as Atmospheric and Oceanic Sciences M203A.) Lecture, three hours. Requisite for undergraduates: Chemistry 20B. Principles of chemical kinetics, thermodynamics, spectroscopy, and photochemistry; chemical composition and history of Earth's atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmosphere chemistry; photochemistry and climate. S/U or letter grading. W

M262B. Atmospheric Diffusion and Air Pollution. (4) (Same as Atmospheric and Oceanic Sciences M224B.) Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complex; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading. Letter grading. Mr. Stolzenbach (Not offered 2013-14)

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 exchange; particulate, droplets, and bubbles; small-scale dispersion and mixing; effect of reactions on transport; linkages between physical, chemical, and biological processes. Letter grading. Mr. Stolzenbach

263B. Advanced Topics in Transport in 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 aquifer sediments, porous aggres, and vegetative canopies. Discussion of theoretical models and experimental observations. Application to important environmental engineering problems. Letter grading. Mr. Stolzenbach

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 (Not offered 2013-14)

265B. Contaminant Transport in Soils and Groundwater. (4) Lecture, four hours; computer applications, two hours; outside study, six hours. Requisites: courses 250B, 265A. Numerical transport model as they apply in soil and groundwater, independent estimation of transport model parameters, remediating hazardous waste sites. Letter grading. Mr. Stolzenbach (Not offered 2013-14)

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. Ms. Mahendra (Sp)

267. Environmental Applications of Geochemical Modeling. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Geochemical modeling is important tool for predicting environmental impacts of contamination. Hands-on experience in modeling using geochemical software packages commonly found in environmental consulting industry to gain better understanding of governing geochemical principles pertaining to movement and transformation of contaminants. Types of modeling include speciation calculations, solid-liquid-gas partitioning, reaction path, inverse mass balance, and reactive transport modeling. Case studies involve acid mine drainage, nuclear waste disposal, bioavailability and risk assessment, mine tailings and mining waste, deep well injection, and microbial respiration. Research/modeling project required. Letter grading. Ms. Jay (Sp)

C282. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, discussion; two hours, outside study, six hours. Correlation, analysis, and metrication of aspects of pavement design, including materials selection and traffic loading and volume. Special attention to aspects of pavement distress diagnosis and relating these into metrics of pavement performance. Discussion of potential choices of pavement materials (i.e., asphalt and concrete) and their specific strengths and weaknesses in pavement performance, implication and correlation of different variables that influence pavement performance and highlight their relevance in pavement design. Concurrently scheduled with course C281. Letter grading. Mr. Stolzenbach (Sp)

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

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

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Milos D. Ercegovac, Ph.D.
Deborah L. Estrin, Ph.D. (Jonathan B. Postel Professor of Networking)
Eliezer M. Gafni, Ph.D.
Mario Gerla, Ph.D.
Richard E. Korf, Ph.D.
Christopher J. Lee, Ph.D.
Songwu Lu, Ph.D.
Stanley J. Osher, Ph.D.
Rafail Ostrovsky, Ph.D.
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Lawrence P. McNamee, Ph.D.
Allen Klinger, Ph.D.
Leonard Kleinrock, Ph.D.
Sheila A. Greibach, Ph.D.
Thelma Estrin, Ph.D.

Associate Professors
Junghoo (John) Cho, Ph.D.
Eleazar Eskin, Ph.D.
Tod D. Millestein, Ph.D.
Glenn D. Reinman, Ph.D.
Yuval Tamir, Ph.D.

Assistant Professors
Tyson Condie, Ph.D.
Jason Ernst, Ph.D.
Alexander Sherstov, Ph.D.
Zhuowen Tu, Ph.D.
Jennifer W. Vaughan, Ph.D. (Symantec Term Professor of Computer Science)

Senior Lecturers S.O.E.
Paul R. Eggert, Ph.D.
David A. Smallberg, M.S.

Senior Lecturer S.O.E. Emeritus
Leon Levine, M.S.

Adjunct Professors
David E. Heckerman, Ph.D.
Van Jacobson, Ph.D.
Alan C. Kay, Ph.D.
Rupak Majumdar, Ph.D.
Peter S. Pao, Ph.D.
Peter L. Reiter, Ph.D.
M. Yahya Sanadidi, Ph.D.

Adjunct Associate Professors
Edward W. Kohler, Ph.D.
Giovanni Pau, Ph.D.

Adjunct Assistant Professors
Carey S. Nachenbarg, M.S.
Ani Nahapetian, Ph.D.

Visiting Assistant Professor
Louis-Noel Pouchet, Ph.D.

Scope and Objectives

Computer science is concerned with the design, modeling, analysis, and applications of computer-related systems. Its study at UCLA provides education at the undergraduate and graduate levels necessary to understand, design, implement, and use the software and hardware of digital computers and digital systems. The programs provide comprehensive and integrated studies of subjects in computer system architecture, computer networks, distributed computer systems, programming languages and software systems, information and data management, artificial intelligence, computer science theory, computational systems biology and bioinformatics, 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 research laboratories specializing in areas such as distributed systems, multimedia computer communications, distributed sensor networks, VLSI systems, VLSI CAD, embedded and reconfigurable systems, computer graphics, bioinformatics, and artificial intelligence. Also, the Cognitive Systems Laboratory is engaged in studying computer systems that emulate or support human reasoning.

The Biocybernetics Laboratory is...
devoted to multidisciplinary research involving the application of engineering and computer science methods to problems in biology and medicine.

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

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

**Department Mission**

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

**Computer Science and Engineering Undergraduate Program Objectives**

The computer science and engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

The computer science and engineering curricula are designed to prepare students for employment in a wide spectrum of high-technology industries.

Computer Science students work with an autonomous maze-solving micromouse robot as an exercise of skills in circuit design, microcontroller programming, circuit debugging, feedback control, and sensor fusion.

**Undergraduate Study**

The Computer Science and Engineering undergraduate program educational objectives are that our alumni (1) make valuable technical contributions to design, development, and production in their practice of computer science and related engineering or application areas, particularly in software systems and algorithmic methods, (2) demonstrate strong communication skills and the ability to function effectively as part of a team, (3) demonstrate a sense of societal and ethical responsibility in their professional endeavors, and (4) engage in professional development or postgraduate education to pursue flexible career paths amid future technological changes.

**Computer Science Undergraduate Program Objectives**

The computer science program is accredited by the Computing Accreditation Commission of ABET, http://www.abet.org.

The computer science undergraduate program educational objectives are that our alumni (1) make valuable technical contributions to design, development, and production in their practice of computer science and related engineering or application areas, particularly in software systems and algorithmic methods, (2) demonstrate strong communication skills and the ability to function effectively as part of a team, (3) demonstrate a sense of societal and ethical responsibility in their professional endeavors, and (4) engage in professional development or postgraduate education to pursue flexible career paths amid future technological changes.

**Computer Science and Engineering B.S.**

**Capstone Major**

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

**Preparation for the Major**

**Required:** Chemistry and Biochemistry 20A; Computer Science 1, 31, 32, 33, 35L, M51A, M51B (or Electrical Engineering M116); Electrical Engineering 10; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, 4AL, 4BL.

**The Major**

**Required:** Computer Science 111, 118, 131, M151B (or Electrical Engineering M116C), M152A (or Electrical Engineering M116L), 180, 181, Electrical Engineering 102, 110,
110L, Statistics 100A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Computer Science 152B); three elective courses selected from Electrical Engineering 113, 113D, 115A, 115C, 132A, 141, 181D; and three upper division computer science elective courses (12 units), one of which must be selected from Computer Science 143 or 161 or 174A. The remaining two elective courses must be selected from Computer Science 112, 114, M117 (or Electrical Engineering M117), CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130, 132, 133, 136, 143, 144, 151C, 161, 170A, M171L (or Electrical Engineering M171L), 174A, 174B, C174C, 183, M184 (or Bioengineering M184 or Computational and Systems Biology M184), CM186 (or Bioengineering CM186 or Computational and Systems Biology M186), CM187 (or Bioengineering CM187 or Computational and Systems Biology M187). Computer Science 103 may be substituted for one elective (credit is not given for both Computer Science 170A and Electrical Engineering 103 unless one of the courses is included in the technical breadth area); 4 units of either Computer Science 194 or 199 may be applied as an elective by petition.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

**Computer Science B.S.**

**Capstone Major**

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.

**Preparation for the Major**

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

**The Major**

**Required:** Computer Science 111, 118, 131, M151B (or Electrical Engineering M16C), M152A (or Electrical Engineering M16L), 180, 181, Statistics 100A; three science and technology courses (12 units) not used to satisfy other requirements, that may include three upper division computer science courses or three courses selected from an approved list available in the Office of Academic and Student Affairs; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone software engineering or design course from Computer Science 130 or 152B, and five upper division computer science elective courses (20 units), two of which must be selected from Computer Science 143, 161, or 174A and one of which must be from 112 or 170A or Electrical Engineering 103 (credit is not given for both Computer Science 170A and Electrical Engineering 103 unless one of the courses is included in the technical breadth area). The remaining two elective courses must be selected from Computer Science 112, 114, M117 (or Electrical Engineering M117), CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130 (unless taken as a required course), 132, 133, 136, 143, 144, 151C, 152B (unless taken as a required course), 161, 170A, M171L (or Electrical Engineering M171L), 174A, 174B, C174C, 183, M184 (or Bioengineering M184 or Computational and Systems Biology M184), CM186 (or Bioengineering CM186 or Computational and Systems Biology M186), CM187 (or Bioengineering CM187 or Computational and Systems Biology M187). If students have not taken Computer Science 130, one elective course must be 132; 4 units of either Computer Science 194 or 199 may be applied as an elective by petition.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

**Bioinformatics Minor**

The Bioinformatics minor introduces undergraduate students to the emerging interdisciplinary field of bioinformatics, an active area of research at UCLA combining elements of the computational sciences with the biological sciences. The minor organizes the many course offerings in different UCLA departments into a coherent course plan providing students with significant training in bioinformatics in addition to the training they obtain from their major. Students who complete the minor will be strong candidates for admission to Ph.D. programs in bioinformatics as well as have the relevant training to obtain jobs in the biotechnology industry.

Students complete a core curriculum and an elective course and are strongly encouraged to participate in undergraduate research as early as possible in one of the many groups offering research opportunities in bioinformatics.

To enter the minor, students must be (1) in good academic standing (2.0 grade point average or better), (2) have completed at least two of the lower division requirements with minimum grades of C, and (3) file a petition in the Office of Academic and Student Affairs of the Henry Samueli School of Engineering and Applied Science, 6426 Boelter Hall.

**Required Lower Division Courses (14 units minimum):** Computer Science 32 or Program in Computing 10C, Life Sciences 3, 23L, Mathematics 33A.

**Required Upper Division Courses (18 units minimum):** Computational and Systems Biology M184 (or Computer Science M184), Computer Science 180 (or Mathematics 182), two courses from Computer Science CM121 (or Chemistry and Biochemistry CM160A), CM122 (or Chemistry and Biochemistry CM160B), CM124 (or Human Genetics CM124), 130 (unless taken as a required course), 132, 133, 136, 143, 144, 151C, 152B (unless taken as a required course), 161, 170A, M171L (or Electrical Engineering M171L), 174A, 174B, C174C, 183, M184 (or Bioengineering M184 or Computational and Systems Biology M184), CM186 (or Bioengineering CM186 or Computational and Systems Biology M186), CM187 (or Bioengineering CM187 or Computational and Systems Biology M187). If students have not taken Computer Science 130, one elective course must be 132; 4 units of either Computer Science 194 or 199 may be applied as an elective by petition.

Students are strongly encouraged to take Computer Science M184 as early as possible to obtain an overview of computational biology.

A minimum of 20 units applied toward the minor requirements must be in addition to units applied toward major requirements or another minor.

If students complete some of the minor requirements as part of their major program,
they can take additional courses from the bioinformatics elective course list.

All minor courses must be taken for a letter grade, and students must have a minimum grade of C (2.0) in each and an overall C average. Successful completion of the minor is indicated on the transcript and diploma.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gradlib/library/pgmreqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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 (Computer Science M.S./Management M.B.A.) 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 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, 199; Electrical Engineering 100, 101A, 102, 103, 110L, M116L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Breadth Requirement. M.S. degree students must satisfy the computer science breadth requirement by the end of the third term in graduate residence at UCLA. The requirement is satisfied by mastering the contents of five undergraduate courses or equivalent: Computer Science 180, two courses from 111, 118, and M151B, one course from 130, 131, or 132, and one course from 143, 161, or 174A. A UCLA undergraduate course taken by graduate students cannot be used to satisfy graduate degree requirements if students have already received a grade of B– or better for a course taken elsewhere that covers substantially the same material.

For the M.S. degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory. Competence in any or all courses in breadth requirements may be demonstrated in one of three ways:

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

Comprehensive Examination Plan

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

Thesis Plan

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

The thesis is a report on the results of student investigation of a problem in the major field of study under the supervision of the thesis committee, which approves the subject and plan of the thesis and reads and approves the complete manuscript. While the problem may be one of only limited scope, the thesis must exhibit a satisfactory style, organization, and depth of understanding of the subject. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

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

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

Computer Science Ph.D.

Major Fields or Subdisciplines

Artificial intelligence; computational systems biology; computer networks; computer science theory; computer system architecture; graphics and vision; information and data management; and software systems.

Course Requirements

Normally, students take courses to acquire the knowledge needed to prepare for the written and oral examinations and for conducting Ph.D. research. The basic program of study for the Ph.D. degree is built around the major field requirement and two minor fields. The major field and at least one minor field must be in computer science.

The fundamental examination is common for all Ph.D. candidates in the department and is also known as the written qualifying examination. To satisfy the major field requirement, students are expected to attain a body of knowledge contained in six courses, as well as the current literature in the area of specialization. In particular, students are required to take a minimum of four graduate courses in the major field of Ph.D. research, selecting these courses in accordance with guidelines specific to the major field. Guidelines for course selection in each major field are available from the departmental Student Affairs Office. Grades of B– or better, with a grade-point average of at least 3.33 in all courses used to satisfy the major field requirement, are required. Students are required to satisfy the major field requirement within the first nine terms after enrolling in the graduate program.

Each minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. By petition and administrative approval, a minor field may be satisfied by examination.

Breadth Requirement. Ph.D. degree students must satisfy the computer science breadth requirement by the end of the third term in graduate residence at UCLA. The requirement is satisfied by mastering the contents of five undergraduate courses or equivalent: Computer Science 180, two courses from 111, 118, and M151B, one course from 130, 131, or 132, and one
course from 143, 161, or 174A. A UCLA undergraduate course taken by graduate students cannot be used to satisfy graduate degree requirements if students have already received a grade of B– or better for a course taken elsewhere that covers substantially the same material.

For the Ph.D. degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory (in addition to the three terms of 201 that may have been completed for the M.S. degree). 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**

The written qualifying examination consists of a high-quality paper, solely authored by the student. The paper can be either a research paper containing an original contribution or a focused critical survey paper. The paper should demonstrate that the student understands and can integrate and communicate ideas clearly and concisely. It should be approximately 10 pages single-spaced, and the style should be suitable for submission to a first-rate technical conference or journal. The paper must represent work that the student did as a graduate student at UCLA. Any contributions that are not the student’s own, including those of the student’s adviser, must be explicitly acknowledged in detail. Prior to submission, the paper must be reviewed by the student’s adviser on a cover page with the adviser’s signature indicating review. After submission, the paper must be reviewed and approved by at least two other members of the faculty. There are two deadlines a year for submission of papers.

After passing the preliminary examination and coursework for the major and minor fields, the student should form a doctoral committee and prepare to take the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, must hold appointments in the department. The remaining member must be a UCLA faculty member in another department. The nature and content of the oral qualifying 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.

**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 that 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**

The computational systems biology (CSB) field can be selected as a major or minor field for the Ph.D. or as a specialization area for the M.S. degree in Computer Science. Graduate studies and research in the CSB field are focused on computational modeling and analysis of biological systems and biological data.

Core coursework is concerned with the methods and tools development for computational, algorithmic, and dynamic systems network modeling of biological systems at molecular, cellular, organ, whole organism, or population levels—and leveraging them in biosystem and bioinformatics applications. Methodological studies include bioinformatics and systems biology modeling, with a focus on genomics, proteomics, metabolomics, and higher levels of biological/physiological organization, as well as multiscale approaches integrating the parts.

Typical research areas with a systems focus include molecular and cellular systems biology, organ systems physiology, medical, pharmacological, pharmacokinetic (PK), pharmacodynamic (PD), toxicokinetic (TK),
physiologically based PBPK-PD, PBTK, and pharmacogenomic system studies; neurosystems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. Typical research areas with a bioinformatics focus include development of computational methods for analysis of high-throughput molecular data, including genomic sequences, gene expression data, protein-protein interaction, and genetic variation. These computational methods leverage techniques from both statistics and algorithms.

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

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

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

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

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

The term theoretical computer science has come to be applied nationally and intentionally to a certain body of knowledge emphasizing the interweaving themes of computability and algorithms, interpreted in the broadest sense. Under computability, one includes questions concerning which tasks can and cannot be performed by information systems of different types restricted in various ways, as well as the mathematical analysis of such systems, their computations, and the languages for communication with them.

Under algorithms, one includes questions concerning (1) how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), (2) how efficiently a proposed system performs a task in terms of resources used, and (3) the limits on how efficiently a task can be performed. These questions are often addressed by first developing models of the relevant parts of an information processing system (e.g., the processors, their interconnections, their rules of operation, the means by which instructions are conveyed to the system, or the way the data is handled) or of the input/output behavior of the system as a whole. The properties of such models are studied both for their own interest and as tools for understanding the system and improving its performance or applications.

**Computer System Architecture**
Computer system architecture deals with the design, implementation, and evaluation of computer systems and their building blocks. It deals with general-purpose systems as well as embedded special-purpose systems. The field also encompasses the development of tools to enable system designers to describe, model, fabricate, and test highly complex computer systems.

Computer systems are implemented as a combination of hardware and software. Hence, research in the field of computer architecture often involves both hardware and software issues. The requirements of application software and operating systems, together with the capabilities of compilers, play a critical role in determining the features implemented in hardware. At the same time, the computer architect must also take into account the capabilities and limitations of the underlying implementation technology as well as of the design tools.

The goal of research in computer architecture is to develop building blocks, system organizations, design techniques, and design tools that lead to improved performance and reliability as well as reduced power consumption and cost.

Corresponding to the richness and diversity of computer systems architecture research at UCLA, a comprehensive set of courses is offered in the areas of advanced processor architecture, arithmetic processor systems, parallel and distributed architectures, fault-tolerant systems, reconfigurable systems, embedded systems, and computer-aided design of VLSI circuits and systems.

1. **Novel architectures** encompass the study of computations that 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.

2. 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.

3. The study of computational algorithms and structures deals with the relationship between computational algorithms and the physical structures that 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.

4. Computer-aided design of VLSI circuits and systems is an active research area that develops techniques for the automated synthesis and analysis of large-scale systems. Topics include high-level and logic-level synthesis, technology mapping, physical design, interconnect modeling, and optimization of various VLSI technologies such as full-custom designs, standard cells, programmable logic devices (PLDs), multichip modules (MCMs), system-on-a-chip (SaCs), network-on-a-chip (NoC), system-in-a-package (SiPs), and design for nanotechnologies.

5. 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. Application of these systems in medicine and healthcare, multimedia, and finance is being studied in collaboration with other schools on campus.

Graphics and Vision

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

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

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

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

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

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

Facilities
Departmental laboratory facilities for instruction and research include:

Artificial Intelligence Laboratories

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

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

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

Computational Systems Biology Laboratories

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

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

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

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

**Computer Graphics and Vision Laboratories**

**Center for Image and Vision Science (CIVS)**

**W. M. Keck Laboratory for Computer Vision**
The laboratory, sponsored by a grant from the W. M. Keck Foundation, hosts a variety of high-end equipment for vision research including a full 360-degree light dome, 3-D laser scanners, cameras, lights, lenses, mobile robots, and virtual reality setup to support vision research in the departments of Statistics, Computer Science, Psychology, and Neuroscience.

**MAGIX: Modeling Animation and Graphics Laboratory**
The MAGIX: Modeling Animation and Graphics Laboratory is used for research on computer graphics, especially targeted towards the video game and motion picture industries, with emphasis on geometric, physics-based, and artificial life modeling and animation, including motion capture techniques, biomechanical simulation, behavioral animation, and graphics applications of machine learning, AI, and robotics. See http://www.magix.ucla.edu.

**UCLA Collective on Vision and Image Sciences**

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

**Computer Networks Laboratories**

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

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

**Internet Research Laboratory**
The Internet Research Laboratory (IRL) is used for exploring the forefront of current Internet architecture and protocol development, including quantifying the dynamics in large-scale networks and securing large-scale systems such as the Internet routing infrastructure and Domain Name System (DNS). See http://irl.cs.ucla.edu.

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

**Computer Science Theory Laboratories**

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

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

**Computer Systems Architecture Laboratories**

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

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

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

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

Information and Data Management Laboratories

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

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

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

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

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

Software Systems Laboratories

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

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

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

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

Software Systems Laboratory
The Software Systems Laboratory is used for research into the design, implementation, and evaluation of operating systems, networked systems, programming languages, and software engineering tools.

Some of these research laboratories also provide support for upper division and/or graduate courses.

Computing Resources

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

Hardware
Computing facilities range from large campus-operated supercomputers to a major local network of servers and workstations that are administered by the department computing facilities (DCF) or school network (SEASnet).

The departmental research network includes Oracle servers and shared workstations, on the school's own ethernet TCP/IP local network. A wide variety of peripheral equipment is also part of the facility, and many more research-group workstations share the network; the total number of machines exceeds 700, the majority running the Linux operating system. The network consists of switched 10/100/1000 ethernet to the desktop with a gigabit backbone connection. The department LAN is connected to the campus gigabit backbone. An 802.11g wireless network is also available to faculty, staff, and graduate students.

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

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

Faculty Areas of Thesis Guidance

Professors

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

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

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

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

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

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

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

Mario Gerla, Ph.D. (UCLA, 1973)
Wireless ad-hoc networks; MAC, routing and transport protocols, vehicular communications, peer-to-peer mobile networks, personal-area networks (Bluetooth and Zigbee), underwater

* Also Professor of Medicine
sensor networks, Internet transport protocols (TCP, streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocols performance evaluation

Richard E. Kort, Ph.D. (Cornell, 1983)

Problem solving, heuristic search, planning in artificial intelligence

Christopher J. Lee, Ph.D. (Stanford, 1993)

Bioinformatics and information theory of experiment planning, inference, and evolution

Songwu Lu, Ph.D. (Illinois, 1990)

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, econometrics, and information economics


Scientific computing and applied mathematics

* Raffi Ostrovsky, Ph.D. (MIT, 1992)

Theoretical computer science algorithms, cryptography, complexity theory, randomization, network protocols, geometric algorithms, data mining

Jens Palsberg, Ph.D. (Aarhus U., Denmark, 1992)

Compiler, embedded systems, programming languages

D. Stott Parker, Jr., Ph.D. (Illinois, 1978)

Data mining, information modeling, scientific computing, visualization, databases and knowledge-based systems

Modrag Potkonjak, Ph.D. (UC Berkeley, 1991)

Computer-aided analysis and synthesis of system level designs, behavioral synthesis, and interaction between high-performance application-specific computations and communications

Amit Sahai, Ph.D. (UC Berkeley, 2001)

Communication, computation theory and practice, algorithms and complexity, discrete system theory, developmental and probabilistic systems

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

Thelma Estrin, Ph.D. (Wisconsin, 1961)

Biomedical engineering, application of technology and computers to health care, computer methods in neuroscience, engineering education

Sheila A. Greibach, Ph.D. (Harvard, 1963)

Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability

Leonard Kleinrock, Ph.D. (MIT, 1963)

Computer networks, computer-communication systems, resource sharing and allocation, computer systems modeling and 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, nomadic computing, and distributed and parallel processing systems

Allen Klinger, Ph.D. (UC Berkeley, 1966)

Pattern recognition, picture processing, biomedical applications, mathematical modeling

Lawrence P. McNamee, Ph.D. (Pittsburgh, 1964)

Graphical computer-aided design, digital filtering, visual design, LSI fabrication techniques, printed circuit board design

Michel A. Melkanoff, Ph.D. (UCLA, 1955)

Physics, information theory, decision theory, design of HIV vaccines, and genome-wide association studies

Thelma Estrin, Ph.D. (Wisconsin, 1961)

Biomedical engineering, application of technology and computers to health care, computer methods in neuroscience, engineering education

Sheila A. Greibach, Ph.D. (Harvard, 1963)

Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability

Leonard Kleinrock, Ph.D. (MIT, 1963)

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Graphical computer-aided design, digital filtering, visual design, LSI fabrication techniques, printed circuit board design

Michel A. Melkanoff, Ph.D. (UCLA, 1955)

Programming languages, data structures, database design, relational models, simulation systems, robotics, computer-aided design and manufacturing, numerical-controlled machinery


Multimedia systems, database systems, data mining

Judea Pearl, Ph.D. (Polytechnic Institute of Brook-lyn, 1965)

Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference, causal and counterfactual analysis

David A. Renshaw, Ph.D. (UC Berkeley, 1975)

Digital computer architecture and design, fault-tolerant computing, digital arithmetic


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

Associate Professors

Jungchul (John) Cho, Ph.D. (Stanford, 2002)

Databases, web technologies, information discovery and integration

Elezar Eskin, Ph.D. (Columbia, 2002)

Bioinformatics, genomics, genomics, machine learning


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

Glenn D. Reinman, Ph.D. (U. San Diego, 2001)

Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multithreaded/multiprocessor design

Amit Sahai, Ph.D. (MIT, 2000)

Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory

Yuvraje Tamir, Ph.D. (UC Berkeley, 1985)

Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection networks and switches, multi-core architectures, reconﬁgurable systems

Assistant Professors

Tyson Condie, Ph.D. (U. Berkeley, 2010)

Large-scale distributed data management, declarative languages, systems for machine learning and big data analysis

Jason Ernst, Ph.D. (UCLA, 2008)

Computational biology, bioinformatics, machine learning

Alexander Sherstov, Ph.D. (Texas, Austin, 2009)

Complexity theory with a focus on communication and circuit complexity, computational learning theory, quantum computing

Zhuowen Tu, Ph.D. (Cornell, 2002)

Statistical modeling/computing, computational biology, machine learning, brain imaging

Jennifer W. Vaughan, Ph.D. (U. Pennsylvania, 2009)

Machine learning, computational/algorithms economics, social network theory, algorithms

Senior Lecturers S.O.E.

Paul R. Eggert, Ph.D. (UCLA, 1980)

Programming languages, operating systems principles, compilers, Internet

David A. Smalley, M.S. (UCLA, 1978)

Programming languages, software development

Senior Lecturer S.O.E. Emeritus

Leon Levine, M.S. (MIT, 1949)

Computer methodology

Adjunct Professors

David E. Heckerman, Ph.D. (UCLA, 1979)

Models and methods used for statistics and data analysis, machine learning, probability theory, decision theory, design of HIV vaccines, and genome-wide association studies

Van Jacobson, Ph.D. (U. Arizona, 1972)

Named data networking (NDN), content-centric networking

Alan Kay, Ph.D. (Utah, 1969)

Object-oriented programming, personal computing, graphical user interfaces

Rupak Majumdar, Ph.D. (UC Berkeley, 2003)

Computer-aided verification of hardware and software systems; logic and automata theory; embedded, hybrid, and probabilistic systems

Peter S. Pao, Ph.D. (U. Michigan, 1975)

Optimizing technology investment and drive growth, knowledge management and technology networking to encourage free flow of knowledge and performance exchange

Peter L. Reif, Ph.D. (UCLA, 1987)

Computer and network security, ubiquitous computing, file systems, distributed systems

* Also Professor of Mathematics
† Member of Brain Research Institute

Computer Science / 65
Mr. Dyer (F, W)

Mr. Palsberg, Mr. Smallberg (W, Sp)

33. Introduction to Computer Organization. (5) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced requisites: courses 28 and 32. Introductory course on computer architecture, assembly language, and operating systems fundamentals. Number systems, machine language, and assembly language. Processors, memory, buses, and traps. Assemblers, linkers, and loaders. Operating system concepts: processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading. 
Mr. Palsberg, Mr. Smallberg (F, Sp)

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

50A, Logic Design of Digital Systems. (4) (Same as Electrical Engineering M161) Lecture, four hours; discussion, two hours; outside study, six hours. Introductory to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control sections. Number systems and arithmetic and computer code for digital information. Letter grading. 
Mr. Ercegovac, Mr. Potkonjak (F, Sp)

97. Variable Topics in Computer Science. (1 to 4) Lecture, one to four hours; discussion, zero to two hours. Designed for freshmen/sophomores. Variable topics in computer science not covered in regular computer science courses. May be repeated once for credit with topic or instructor change. Letter grading. 
Mr. Smolberg

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.

Computer Science Lower Division Courses 1. Freshman Computer Science Seminar. (1) Seminar, one hour; discussion, one hour. Introduction to departments and programs and key ideas in computer science and computer engineering. Assignments given to bolster independent study and writing skills. Letter grading. 
Mr. Palsberg (F)

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

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.

199. Directed Research in Bioinformatics. (2 to 4) Tutorial, six to 12 hours. Limited to juniors/seniors. Supervised individual research under guidance of faculty mentor. Culuminating paper required. May be repeated for credit. Individual contract required. Letter grading.

Upper Division Course 199. Directed Research in Bioinformatics. (2 to 4) Tutorial, six to 12 hours. Limited to juniors/seniors. Supervised individual research under guidance of faculty mentor. Culuminating paper required. May be repeated for credit. Individual contract required. Letter grading.

Mr. Eggert (F, Sp)

112. Modeling Uncertainty in Information Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: Statistics 100A or Statistics 100B or Statistics 106. Designed for juniors/seniors. Probability and stochastic process models as applied in computer science. Basic methodological tools include random variables, conditional probability, expectation and higher moments, Bayes theorem, Markov chains. Applications include probabilistic algorithms, evidence reasoning, analysis of algorithms and data structures, reliability, communication protocol and queueing models and robustness. Letter grading. 

114. Peer-to-Peer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 118. Recommended requisite: course 111. Optional: course 218. Fundamental concepts on peer-to-peer networks, such as distributed hash-tables, routing, searching, and related network management protocols (Join, Leave, death management, routing, table repair). Video streaming and Internet Protocol (IPv) and applications, with emphasis on the issues with such as PDAs and smartphones. Introduction to mesh-based and tree-based topologies for live streaming, with emphasis on key aspects of peer selection, and the configuration and use of common optimization techniques (peer capacity, network delay). Hands-on approach to guide students to development and testing of actual experimental system on PlanetLab. Letter grading. 
Mr. Gerla (W)

M117. Computer Networks: Physical Layer. (4) (Same as Electrical Engineering M117.) Lecture, two hours; discussion, four hours; laboratory, two hours; outside study, six hours. Not open to students with credit for course M171L. Introduction to fundamental computer communication concepts underlying and supporting modern networks, with a focus on wireless communications and media access layers of network protocol stack. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environment awareness, and experimental laboratory sessions included. Letter grading. 
Mr. Gerla (F)

M118. Computer Network Fundamental. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 35L or Program in Computing 10C. Designed for juniors/seniors. Introduction to design and performance evaluation of computer networks, including such topics as what protocols are, layered network architecture, Internet protocols, architecture, network applications, transport protocols, routing algorithms and protocols, internetworking, congestion control, and link layer protocols including Ethernet and wireless channels. Letter grading. 
Mr. Gerla, Ms. Zhang (F, Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Enforced requisites: course 32 or Program in Computing 10C with grade of C- or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A. Prior knowledge of biological data not required. Designed for engineering students as well as students from life sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on concepts of bioinformatics and alignment algorithms. Concurrently scheduled with course CM221. P/NP or letter grading.

CM122. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Recommended requisites: course 32 or Program in Computing 10C with grade of C- or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A.
Course CM121 is not requisite to CM122. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genetic variation and computational interdisciplinary research in genetics. Topics include introduction to genetics, identification of genes involved in disease, inferring human population history, technologies for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and then solving those problems using computational tools from statistics and computer science. Concurrently scheduled with course CM224. Letter grading.

Mr. Eggert, Mr. Esin (Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and Mathematics 16A or 16B. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genetic variation and computational interdisciplinary research in genetics. Topics include introduction to genetics, identification of genes involved in disease, inferring human population history, technologies for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and then solving those problems using computational tools from statistics and computer science. Concurrently scheduled with course CM224. Letter grading.

Mr. Esin (Sp)

131. Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32, 33L. Recommended: Engineering 138EW or 139EW. Structured programing, program specification, program proving, modularity, abstract data types, composite design, software tools, software control systems, program testing, team programming. Letter grading.

Mr. Eggert, Mr. Majumdar (F,Sp)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 32, 33L, 131, 181. Compiler structure; lexical and syntactic analysis; semantic analysis; code generation; theory of compiler writing. Letter grading.

Mr. Eggert, Mr. Palsberg (F)

133. Parallel and Distributed Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 111 (may be taken concurrently), 131. Distributed memory and shared memory parallel architectures; asynchronous parallel languages: MPI, Message Passing Interface for parallel computing; implementation of parallel programs for scientific computation and distributed systems. Letter grading.

Mr. Cong (W)

136. Introduction to Computer Security. (4) Lecture, technical sciences and medical school. Development of computer security and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving those problems using algorithmic techniques and theories. Topics include cryptography and security policies, authentication, authorization, access control, and operations research techniques. Letter grading.

Mr. Eggert, Mr. Reifner (F)


Mr. Parker (W)
properties, pumping lemmas, and decision algo-
rithms. Introduction to computability. Letter grading.
Mr. Ostrovsky, Mr. Sahai (Sp)

183. Introduction to Cryptography. (4) Lecture, four hours;
discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory. Enforced requisite: course 180. Introduction to cryptography, complexity, security, and basic con-
cepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudo-
random generators, pseudorandom functions and permutations, semantic security, public-key and private-key encryption, key-agree-
ment, homomorphic encryption, private information retrieval and voting protocols, message authentica-
tion, digital signatures, and zero-knowledge proofs, collision-resistant hash functions, commitment protocols, and two-party secure com-
putation with static security. Letter grading.
Mr. Ostrovsky (not offered 2013–14)

M184. Introduction to Computational and Sys-
tems Biology. (2) Formerly numbered M186A. (Same as Bioengineering M184 and Computational and Systems Biology M184.) Lecture, two hours; out-
side study, eight hours. Enforced requisite: course 118. Introduction to computational and systems biology and computa-
tion in biology. Modern biological systems are driven by high-
throughput technologies that generate huge amounts of data and computational simulations and algorithms. This course presents biological and computational models and their analysis using modern computational and software tools. Topics include both general ideas and specific case studies in systems biology. Letter grading.

CM186. Computational Biomedical Modeling, Simu-
lation and Imaging of Biological Systems. (F) Formerly numbered CM186B. (Same as Bioengineering CM186 and Computational and Systems Biology M186.) Lecture, four hours; discussion, two hours. Preparation: course 180. Introduction to modeling and simulating biological systems. Emphasis on computer simulation and the analysis of the behavior of large systems. Applications to a range of biological problems. Topics include modeling of biological molecules, gene networks, cellular networks, and neural networks. Letter grading.

CM187. Research Communication in Computa-
tional and Systems Biology. (2, 4) Formerly num-
bered CM187C. (Same as Bioengineering CM187 and Computational and Systems Biology M187.) Lecture, four hours; outside study, eight hours. Requis-
ite: course CM186. Closely directed, interactive, and real research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and ca-
pabilities. Critiques of oral presentations and written progress reports explained in detail and following them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading.

CM188. Special Courses in Computer Science. (4) Lecture; four hours; outside study, eight hours.Spe-
tial courses in computer science for undergraduate students taught on an experimental or developmental basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Computer Sci-
ence. (1) Seminar, four hours; outside study, eight hours. Members of the research group who are part of research group. Discussion of research meth-
ods and current literature in field or of research of fac-
tory members or students. May be repeated for credit. Letter grading.
Mr. Potkonjak (W,Sp)

195. Research in Computer Science. (3-6) Tutorial, to be arranged. Limited to juniors/se-
niors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with school approval. Individual contract required; enrollment
petitions available in Office of Academic and Student Affairs. Letter grading.

Graduate Courses

201. Computer Science Seminar. (2) Seminar, four hours; outside study, two hours. Designed for gradu-
ate computer science students. Seminars on current research topics in computer science. May be repeat-
ed for credit. S/U grading.

202. Advanced Computer Science Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: comprehensive examination in computer science. Current computer science re-
search into theory of, analysis and synthesis of, and applications of information processing systems. Each member of the seminar will present one or more original pieces of work in one specialized area. May be repeated for credit. Letter grading.
Ms. Estrin

211. Network Protocol and Systems Software De-
sign for Wireless Networks. (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 wireless networks. Topics include routing and flow control, ad-hoc routing, and wireless TCP. Letter grading.
Mr. Lu

212A. Queueing Systems Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: course 112, Electrical Engineering 131A. Resource sharing issues and theory of queueing (or queue-line) systems. Review of Markov chains and baby queue theory. Method of stages. M/E/1, E/M/1, Bulk arrival and bulk service systems. Series-parallel stages. Funda-
mentals of open and closed queueing networks. In-
terarrival and service time distributions. Queuing for M/M/1, G/G/1, G/G/M. Little’s theo-
retical marks. Advanced queueing theory: G/G/1; Lind-
ley integral equation; spectral solution. Inequalities, bounds, approximations. Letter grading.
Mr. Gerla

212B. Queuing Applications: Scheduling Algo-
rithms and Queuing Networks. (4) Lecture, four hours; outside study, eight hours. Requisites: course 212A. Priority queueing. Applications to time-sharing scheduling algorithms: FB, Round Robin, Conserva-
tion Law, Bounds. Queuing networks: definitions; job flow balance; product form solutions—local bal-
ces, M/M; computational algorithms for perfor-
ma nce measures: asymptotic behavior and bounds; approximation techniques—diffusion—iterative tech-
niques; applications. Letter grading.

213A. Embedded Systems. (4) (Same as Electrical Engineering M202A.) Lecture, four hours; outside study, eight hours. Requisite: course 111. Designed for graduate computer science and electrical engi-
neering students. Methodologies and technologies for design of embedded systems. Topics include hardware and software platforms for embedded sys-
tems, techniques for modeling and specification of system behavior, software organization, real-time oper-
ating system scheduling, real-time communication and packet scheduling, low-power battery and ener-
gy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hard-
ware and software architecture optimization. Theore-
tical foundations as well as practical design methods. Letter grading.

215. Computer Communications and Cyber-
Physical Systems. (4) (Same as Electrical Engineer-
ing M202B.) Lecture, four hours; outside study, eight hours. Requisite: course M51A or Electrical Engineer-
ing M116B or Electrical Engineering M116C. System-level man-
agement and cross-layer methods for power and en-
ergy consumption in computing and communication at various scales ranging across embedded mobile, personal, enterprise, and data-center scale. Comput-
ing, networking, sensing, and control technologies and algorithms for improving energy sustainability in human–cyber–physical systems. Techniques for mod-
eling of energy consumption, energy sources, and energy storage; dynamic power management; pow-
er-performance scaling and energy proportionality; distributed-aware scheduling; low-power protocols; battery modeling and management; thermal management; sensing of power consumption. Letter grading.
Ms. Estrin, Mr. Srivastava

216. Distributed Multicast Control in Networks. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 212A, 215. Topics from field of distributed control and access in computer networks, including intermediate and end-to-end protocols; satellite packet switching; routing and flow control; satellite and ground radio packet switching; local networks; commercial network services and archi-

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tecture. Optional topics include extended error control techniques; modern; SDLC, HDLC, X.25, etc.; protocol verification; network simulation and measurement; integrated networks; communication protocols. Letter grading.
Mr. Chu

217A. Internet Architecture and Protocols. (4) Lect-

er, four hours; outside study, eight hours. Requisite:
course 118. Focus on mastering existing core set of Internet protocols, including IP, core transport proto-
colos, routing protocols, DNS, NTP, and security pro-
tocols such as DNSSEC, to understand principles behind design of these protocols, appreciate their design tradeoffs, and learn lessons from their opera-
tions. Letter grading.
Ms. Zhang (W)

217B. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Requis-
ite: course 217A. Designed for graduate students. Overview of Internet development history and funda-
mental principles underlying TCP/IP protocol design. Discussion of current Internet research topics, includ-
ing latest research results in routing protocols, trans-

tport protocols, network measurements, network secu-


d

ty protocols, and clean-slate approach to network archi-
tecture design. Fundamentals of Internet network proto-

colos and implementations. Letter grading.
Ms. Zhang (Sp)

218. Advanced Computer Networks. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 112, 118. Review of seven-layer OSI


model, High-speed networks: LANs, MANs, ATM. Flow and congestion control; bandwidth allocation, Internetworking. CM 235. Advanced Operating Systems. (4) Lecture, three and one-half hours; discussion, one hour. Review of current literature on area of operating systems issues through guided conversations with faculty. May be repeated for credit with topic change. Letter grading. Mr. Cong (Not offered 2013-14)

236. Computer Security. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 118. Basic and research material on computer security. Topics include basic principles and goals of computer security, cryptography, database technology, fundamental security protocols, computer forensics, virtual private networks, firewalls, intrusion detection systems. Letter grading. Mr. Palisberg, Mr. Reihler

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

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

241A. Object-Oriented and Semantic Database Systems. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Object database principles and requirements. Data models, accessing and query languages, database management systems, fault recovery techniques, network partitioning, improved transaction management, compilation of transactional programs, distributed transactions, federated databases, data security, database access control. Letter grading. Mr. Cardenas

241B. Pictorial and Multimedia Database Management (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/pictures, video and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and accessing the Internet by alphanumeric, image, video, and audio content. Querying, visual languages, and construction of data access languages. Database design, logical and physical indexing. Internet multimedia streaming. 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, database update, transactional database systems, fault recovery techniques, network partitioning, examples, trade-offs, and design experiences. Letter grading. Mr. Chou

245A. Intelligent Information Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 241A, 255A. Knowledge discovery in database, knowledge-base maintenance, knowledge-

CM 221. Introduction to Bioinformatics. (4) (Same as Bioinformatics M228A, Chemistry CM268A, and Human Genetics CM269A.) Lecture, four hours; discussion, two hours. Recommended requisites: course 32 or Program in Computing 10C with grade of C– or better, and Mathematics 170A or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and computer science. Concurrenly scheduled with course CM121, S/U or letter grading. Mr. Eskin (F)

CM 222. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Bioinformatics M228B, Chemistry CM268B, and Human Genetics CM269B.) Lecture, four hours; discussion, two hours. Recommended requisites: course 32 or Program in Computing 10C with grade of C– or better, and Mathematics 170A or Statistics 100A. Course CM221 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrenly scheduled with course CM122. Letter grading. Mr. Eskin

CM 224. Computational Genetics. (4) (Same as Bioinformatics M224A and Human Genetics CM224A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and Biostatistics 100A or 110A or Mathematics 170A or Statistics 100A. Prior knowledge of biology not required. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genomic and proteomic data sets, computational algorithms for searching and analyzing large biological databases. Topics include identification of genes involved in disease, inferring human population history, technologies for obtaining genomic and proteomic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and then solving those problems using computational techniques from statistics and computer science. Concurrenly scheduled with course CM124. Letter grading. Mr. Eskin

CM 229S. Seminar: Current Topics in Bioinformatics. (4) (Same as Biological Chemistry M229S and Human Genetics CM229S.) Seminar, four hours; outside study, eight hours. Recommended for graduate students in engineering and in biological sciences and medical school. Review of current topics in bioinformatics, genomics, and computational biology. Exploration of current research in genetics and genomics. Topics include genome analysis, regulatory genomics, association analysis, association study design, isolated and familial diseases, cloning and cultivation of subcellular structure, human structural variation, model organisms, and genomic technologies. Computational techniques include those from statistics and computer science. Must be repeated for credit with topic change. Letter grading. Mr. Eskin (Sp)

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

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

CM 232. Static Program Analysis. (4) Lecture, four hours; outside study, eight hours. Requisite: course 231 or 32. Introduction to static analysis of object-oriented programs and its usage for optimization and bug finding. Class hierarchy analysis, rapid type analysis, equality-based analysis, path analysis, constraint-insensitive and flow-sensitive analysis, context-insensitive and context-sensitive analysis. Soundness proofs for static analyses. Efficient data structures for static analysis information such as directed graphs and binary decision diagrams. Flow-directed method inlining, type-safe method inlining, synchronization optimization, deadlock detection, security vulnerability detection. Formal implementation of variety of static analyses, as well as readings from recent research literature on modern applications of static analysis. Letter grading. Mr. Palisberg

CM 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 multeway rendezvous; synchronous and asynchronous languages: CSP, Ada, Linda, Maize, UC, and others; introduction to parallel program verification. Letter grading. Mr. Cong

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

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

CM 235. Advanced Model-Driven Engineering. (4) Lecture, four hours. Preparation: C or C++ programming experience. Requisite: course 111. In-depth investigation of operating systems issues through guided construction and development of a system for PC machines and consideration of recent literature. Memory management and protection, interrupts and traps, processes, interprocess communication, preemptive multitasking, file systems, Virtualization, networking, profiling, research operating systems. Series of laboratory projects, including extra challenge work. Letter grading. Ms. Eggert (Not offered 2013-14)

CM 241. Pictorial and Multimedia Database Management. (4) Lecture, three and one-half hours; discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/pictures, video, and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and across the Internet using alphanumeric, image, video, and audio content. Querying, visual languages, and construction of data access languages. Database design, logical and physical indexing. Internet multimedia streaming. Other topics at discretion of instructor. Letter grading. Mr. Cardenas

CM 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, database update, transactional database systems, fault recovery techniques, network partitioning, examples, trade-offs, and design experiences. Letter grading. Mr. Chou

CM 245A. Intelligent Information Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 241A, 255A. Knowledge discovery in database, knowledge-base maintenance, knowledge-
246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 112, 143, 180, 181. Designed for graduate students. Scale of Web data requires novel algorithms and architectures. Requisite: course M51A. Detailed study of various physical design aspects and intelligent planning and scheduling systems; computer architecture for processing large-scale knowledge-base/database systems. Letter grading. Mr. Chu

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

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

251B. Parallel Computer Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 111. Design and implementation of high-performance systems, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW processors, branch prediction, instruction-level parallelism, software support for instruction-level parallelism, simulation-based performance analysis and evaluation, state-of-art design examples, introduction to parallel architectures. Letter grading. Mr. Cho (Sp)

252A. Arithmetic Algorithms and Processors. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Number systems: conventional, redundant, signed-digit, and residue. Types of algorithms and implementation: Complexity, asymptotic analysis. Array processing, high-speed VLSI implementation. Techniques for error detection and correction. Letter grading. Mr. Ercegovac, Mr. Tamir (F)

252B. Computer Arithmetic. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. Number systems: conventional, redundant, signed-digit, and residue. Types of algorithms and implementation: Complexity, asymptotic analysis. Array processing, high-speed VLSI implementation. Techniques for error detection and correction. Letter grading. Mr. Ercegovac, Mr. Tamir (F)

252C. Computer Systems Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 251A. SIMD and MIMD systems, symmetric multiprocessors, distributed-shared-memory systems, messages-passing systems, multicores, clusters, interconnect networks, host-network interfaces, switched element design, communication primitives, cache coherence, memory consistency models, synchronization primitives, state-of-art design examples. Letter grading. Mr. Ercegovac, Mr. Tamir (F)

252E. Foundations of VLSI CAD Algorithms. (4) Lecture, four hours; outside study, eight hours. Preparation: one or two semesters of calculus. Complexity, asymptotic analysis. Fast algorithms and implementations for two-oper- and addition, multioperand addition, multiplication, division, and square root. Online arithmetic. Evaluation of transcendental functions. Floating-point arithmetic and numerical error control. Arithmetic error codes. Residue arithmetic. Examples of contemporary arithmetic ICs and processors. Letter grading. Mr. Ercegovac (W)


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

254A. Computer Memories and Memory Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: one graduate course in computer memories. Memory systems; control, access modes, hierarchies, and allocation algorithms. Characteristics, system organization, and device considerations of ferfite memories, thin film memories, and semiconductor memories. Letter grading. Mr. Chu

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

256A. Advanced Scalable Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. State-of-art scalable multiprocessors, Interdependency among instruction-level, software, and hardware architecture, high-performance building blocks, such as chip multiprocessors (CMPs). On-chip and off-chip communication. Mechanisms and overheads of parallelism at multiple levels. Current research areas. Examples of chips and systems. Letter grading. Mr. Tamir (W)

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

M258C. LSI in Computer System Design. (4) Same as Electrical Engineering M216C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M258B. LSI/VLSI design and application in computer systems. In-depth study of VLSI architectures and VLSI design tools. Letter grading.

258E. Foundations of VLSI CAD Algorithms. (4) Lecture, four hours; outside study, eight hours. Preparation: one or two semesters of calculus. Complexity, asymptotic analysis. Fast algorithms and implementations for two-oper- and addition, multioperand addition, multiplication, division, and square root. Online arithmetic. Evaluation of transcendental functions. Floating-point arithmetic and numerical error control. Arithmetic error codes. Residue arithmetic. Examples of contemporary arithmetic ICs and processors. Letter grading. Mr. Ercegovac (W)

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: one graduate course in computer memories. Memory systems; control, access modes, hierarchies, and allocation algorithms. Characteristics, system organization, and device considerations of ferfite memories, thin film memories, and semiconductor memories. Letter grading. Mr. Tamir (F)

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requisite: course M251B. Recommended: one graduate course in computer memories. In-depth study of various problems in analysis and design of high-speed VLSI interconnects at both integrated circuit (IC) and package levels, including interconnect capacitance and resistance; passives and lossless transmission lines; signal transition delay, 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 area of computer science system design in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

260. Machine Learning Theory. (4) Lecture, four hours. Preparation: basic knowledge of probability and ability to read and write mathematical proofs. Theoretical foundations underlying common machine learning algorithms. Topics include introduction to PAC learning model, uniform convergence theory, VC dimension, online learning, no-regret learning, online convex optimization, ensemble methods and boosting, and connections to game theory. Letter grading. Ms. Vaughan

261A. Problem Solving and Search. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. In-depth treatment of systematic problem-solving search algorithms in artificial intelligence, including problem spaces, brute-force search, heu- ristic search, linear-space algorithms, real-time search, heuristic evaluation functions, two-player games, and constraint-satisfaction problems. Letter grading. Mr. Korf (Sp)

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


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. Theo- ry and implementation of systems that emulate or support human reasoning. Current literatures and individual studies in artificial intelligence, knowledge- based systems, decision support systems, computa- tional 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 generation. Examination of both symbolic and statistical approaches to language processing and acquisition. Letter grading. Mr. Dyer (W)

263B. Connectionist Natural Language Processing. (4) Lecture, four hours; outside study, eight hours. Requisite: course 161 or 263A. Examination of connectionist/ANN architectures designed for natural language processing. Issues include localist versus 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

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

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


M266B. Statistical Computing and Inference in Vision and Image Science. (4) (Same as Statistics M323B.) Lecture, three hours. Preparation: basic statistics, linear algebra (matrix analysis), computer vision. Introduction to broad range of algorithms for statistical inference and learning that could be used in vision, pattern recognition, speech, bioinformatics, and data mining. Topics include Markov chain Monte Carlo methods, sequential Monte Carlo methods, importance sampling, sequential Monte Carlo methods, integration, partial differential equations. S/U or letter grading.

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

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 multi-sensor pattern recognition including speed and vision, and adaptive robot control. Students required to present a project report on research in one area of interest. Letter grading.


268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Design for graduate students. Reading and research, discussion of advanced topics and current research in computational neuroscience. Neural networks and connectionism as paradigm for parallel and concurrent computation in application to problems of perception, vision, robot control, navigation, and robotics. May be repeated for credit. S/U grading. Mr. Soatto, Ms. Vaughan (W/Sp)


270B. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Emphasis on evolutionary computation and evolutionary programming, neural networks, medical image analysis, etc. Focus on comprehensive models that can realistically emulate variety of living things (plants and animals) from lower animals to humans. Exercises in computational modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphical entities. Specific topics include modeling plants using L-systems, biomechanical simulation and control, behavioral animation, reinforcement and neural-network learning of locomotion, cognitive modeling, artificial animals and humans, human facial animation, and artificial evolution. Letter grading. Mr. Terzopoulos (Sp)

M276A. Pattern Recognition and Machine Learning. (4) (Same as Statistics M231.) Lecture, three hours. Designed for graduate students. Fundamental concepts and theories in 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, MLD, AIC), PCA/ICA/TCA, MDS, SVM, boosting. S/U or letter grading. Mr. Zhu

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

276C. Speech and Language Communication in Artificial Intelligence. (4) Lecture, four hours; outside study, eight hours. Requisite: course M276A or 276B. Introduction to speech and language communication: interaction with pictorial information systems, sound and symbol generation by humans and machines, semantics of data, systems for speech recognition and understanding. Use of speech and text for computer input and output in applications. Letter grading.

M278. Probabilistic Models of Cognition. (4) (Same as Statistics M239.) Seminar, three hours; discussion, one hour. Requisite: course 180, Mathematics 110B, Statistics 101B, and understanding of human cognition, designing artificial intelligence systems. Introduction to conceptual foundations and basic math-
lectrical and computational techniques. Topics illustrated on different aspects of cognition. S/U or letter grading.

279. Current Topics in Computer Science: Methodology. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer science methodology in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading.

280A-280ZZ. Algorithms. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Basic concepts. Techniques for proving the correctness of algorithms. Theoretical sound techniques for dealing with NP-hard problems. Inability to solve these problems efficiently may mean that an algorithmic solution is based on approximation—finding a solution that is near to best possible in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include primal-dual methods, linear program rounding, greedy algorithms, and local search. Letter grading.

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or equivalent background. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets of strings, characterizations, nondeterminism, decidability, unsolvable problems, "easy" and "hard" problems, PTIME/PP/TIME. Letter grading. Mr. Ostrovsky (W)

281D. Discrete State Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181 or equivalent background. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets of strings, characterizations, nondeterminism, decidability, unsolvable problems, "easy" and "hard" problems, PTIME/PP/TIME. Letter grading. Mr. Ostrovsky (W)

282A. Cryptography. (4) Same as Mathematics M209A. Lecture, four hours; outside study, eight hours. Introduction to theory of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public-key and private-key cryptography, secret-sharing, message authentication, discrete signatures, interaction proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, zero-knowledge proofs in state and system identification and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system modeling, and security. Letter grading. Mr. Ostrovsky (W)

282B. Cryptographic Protocols. (4) Same as Mathematics M209B. Lecture, four hours; outside study, eight hours. Requisite: course M282A. Consideration of advanced cryptographic protocol design and analysis. Topics include noninteractive zero- knowledge proofs; zero-knowledge arguments; concurrent key-agreement, contract signatures, and two-party secure computation with static security. Letter grading. Mr. Ostrovsky (W)

282S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisites: courses 280A, 281A. Intended for students undertakes thesis of advanced topics and current research in such areas as algorithms and complexity models for parallel and concurrent current computation, and formal language and automata theory. May be repeated for credit. S/U grading. Ms. Greibach (Sp)

283A-M283B. Topics in Applied Number Theory. (4-4) (Same as Mathematics M208A-M208B.) Lecture, four hours; outside study, eight hours. Requisite: course 185 or consent of instructor. Topics include cryptography; public-key and discrete log cryptosystems. Attacks on cryptosystems. Primality testing and factorization methods. Elliptic curve cryptography. From ageology: Hamming codes, cyclic codes, Gilbert/Varshamov bounds, Shannon theorem. S/U or letter grading.

284A-284ZZ. Topics in Automata and Languages. (4 each) Lecture, four hours; outside study, eight hours. Requisite: course 181. Additional requisites for each offering announced in advance by department. Selections from families of formal languages, grammars, machines, operators; pushdown automata, context-free languages, and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Subtopics of some current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284P). May be repeated for credit with consent of instructor and topic change. Letter grading. Mr. Sahai (Sp)

CM286. Computational Systems Biology: Modeling and Analysis. (4) (Formerly numbered CM286B.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Corequisite: Electrical Engineering 102. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multicompartamental, predator-prey, pharmacokinetic, and pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biological pathways/networks), organ, and organismic levels. Both theory and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading. Mr. DiStefano (F)

CM287. Research Communication in Computational Systems Biology. (4) Lecture, four hours; outside study, eight hours. Requisite: course CM286. Closey directed, interactive, and research-oriented seminar focused on quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and written progress reports explain how to proceed with research results. Major emphasis on effective research re-reporting, both oral and written. Concurrently scheduled with course CM187. Letter grading. Mr. DiStefano (Sp)

287A. Theory of Program Structure. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Models of computer programs and their structure. Programs, control structures, recursion schemes; equivalence, optimization, correctness, and translatable of programs; expressive power of program constructs and data structures; selected current topics. Letter grading. Mr. Greibach (F)

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisites: courses 280A, 281A. Intended for students undertakes thesis of advanced topics and current research in such areas as algorithms and complexity models for parallel and concurrent current computation, and formal language and automata theory. May be repeated for credit. S/U grading. Ms. Greibach (F)

289A-289ZZ. Current Topics in Computer Theory. (2 to 12 each) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer theory in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. Letter grading.

CM290. Complexity Theory. (4) Lecture, four hours; outside study, eight hours. Diagonalization, polynomial-time hierarchy, PCP theorem, randomness and de-randomization, circuit complexity, attempts and limitations to proving P does not equal NP, average-case complexity, one-way functions, hardness amplification. Problem sets and presentation of previous and original research related to course topics. Letter grading. Mr. Ostrovsky (F)

CM290A. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 280. Introduction to decision making under uncertainty and competitive analysis. Review of current research in online algorithms for problems arising in many areas, such as data and memory management, searching and navigating in unknown terrains, and server systems. Letter grading.

CM291A. Randomized Algorithms. (4) Lecture, four hours; outside study, eight hours. Basic concepts and design techniques for randomized algorithms, such as probability theory, Markov chains, random walks, and probabilistic method. Applications to randomized algorithms in data structures, graph theory, computational geometry, number theory, and parallel and distributed systems. Letter grading.

CM296A. Advanced Modeling Methodology for Dynamic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: Electrical Engineering 141 or 142 or Mathematics 115A or Mathematics 109A and Aerospace Engineering 171A or other course. Development of dynamic systems modeling methodology for physiological, biomedical, pharmaceutical, chemical, and related systems. Control system, multidimensional, nonlinear, 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 (W)

CM296B. Optimal Parameter Estimation and Experimental Design for Biomedical Systems. (4) Same as Bioengineering M296B, Biomathematics M270, and Medicine M270E. Lecture, four hours; outside study, eight hours. Requisite: course CM286 or CM296A or Biomathematics 220. Estimation methodology and model parameter estimation algorithms for dynamic systems modeling. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experimental design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W)

CM296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) Same as Bioengineering M296C and Medicine M270E. Lecture, four hours; outside study, eight hours. Requisite: course CM286 or Medicine M296A. Introduction to mathematical modeling and model parameter estimation algorithms for dynamic systems modeling. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experimental design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W)

CM296D. Introduction to Computational Cardiology. (4) Same as Bioengineering M296D. Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiologic processes. Topics include neural potential (AP), theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of
numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.

Mr. DiStefano, Mr. Kogan

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

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

495. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, six hours. Limited to graduate Computer Science Department students. Seminar on communication of computer science materials in classroom; preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. Mr. Korf

495B. Teaching with Technology. (2) Seminar, two hours; outside study, four hours. Limited to graduate Computer Science Department teaching assistants. Seminar for teaching assistants covering how technology can be used to aid instruction in and out of classroom. S/U grading. Mr. Korf

497D–497E. Field Projects in Computer Science. (4–4) Fieldwork, to be arranged. Students are divided into teams led by instructor; each team is assigned one external company or organization that they investigate as candidate for possible computerization, submitting 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. (1 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. Letter 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 Ph.D. preliminary examinations. S/U grading.

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

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

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

Electrical Engineering

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Eli Yablonovitch, Ph.D.

Adjunct Associate Professor
Keisuke Goda, Ph.D.

Adjunct Assistant Professor
Jin-Hyun Lee, Ph.D.

Scope and Objectives

The Department of Electrical Engineering fosters a dynamic academic environment that is committed to a tradition of excellence in teaching, research, and service and has state-of-the-art research programs and facilities in a variety of fields. Departmental faculty members are engaged in research efforts across several disciplines in order to serve the needs of industry, government, society, and the scientific community. Interactions with other disciplines are strong. Faculty members regularly conduct collaborative research projects with colleagues in the Gelfen School of Medicine, Graduate School of Education and Information Studies, School of Theater, Film, and Television, and College of Letters and Science.

There are three primary research areas in the department: circuits and embedded sys-
tems, physical and wave electronics, and signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunication, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

The program grants one undergraduate degree (Bachelor of Science in Electrical Engineering) and two graduate degrees (Master of Science and Doctor of Philosophy in Electrical Engineering). The graduate program provides students with an opportunity to pursue advanced coursework, in-depth training, and research investigations in several fields.

Department Mission
The education and research activities in the Electrical Engineering Department are aligned with its mission statement. In partnership with its constituents, consisting of students, alumni, industry, and faculty members, the mission of the department is to (1) produce highly qualified, well-rounded, and motivated students with fundamental knowledge of electrical engineering who can provide leadership and service to California, the nation, and the world, (2) pursue creative research and new technologies in electrical engineering and across disciplines in order to serve the needs of industry, government, society, and the scientific community, (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 electrical engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The electrical engineering curriculum provides an excellent background for either graduate study or employment. Undergraduate education in the department provides students with (1) fundamental knowledge in mathematics, physical sciences, and electrical engineering, (2) the opportunity to specialize in specific areas of interest or career aspiration, (3) intensive training in problem solving, laboratory skills, and design skills, and (4) a well-rounded education that includes communication skills, the ability to function well on a team, an appreciation for ethical behavior, and the ability to engage in lifelong learning. This education is meant to prepare students to thrive and to lead. It also prepares them to achieve the following two program educational objectives: (1) that graduates of the program have successful technical or professional careers and (2) that graduates of the program continue to learn and to adapt in a world of constantly evolving technology.

Undergraduate Study
The Electrical Engineering major is a designated capstone major. Undergraduate students complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. Students apply their knowledge and expertise gained in previous mathematics, science, and engineering coursework. Within a multidisciplinary team structure, students identify, formulate, and solve engineering problems and present their projects to the class.

Electrical Engineering B.S.
Capstone Major
The undergraduate curriculum allows Electrical Engineering majors to specialize in one of three emphasis areas or options. The three options are structured as an electrical engineering degree, and the only degree offered to undergraduate students by the department is the Bachelor of Science degree in Electrical Engineering.

No distinction is made among the three options: (1) electrical engineering (EE) option is the regular option that provides students with preparation in electrical engineering with a range of required and elective courses across several disciplines; (2) computer engineering (CE) option provides students with preparation in computer engineering-oriented courses and computer science courses; and (3) biomedical engineering (BE) option provides students with exposure to additional chemistry and life sciences courses and helps them meet most of the premedical preparation requirements so that they are prepared for careers in bioengineering, medicine, or electrical engineering.

Electrical Engineering Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical Engineering 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Electrical Engineering 101A, 101B, 102, 103, 110, 110L, 113, 115A, 115AL, 121B, 131A, 132A, 141, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from one of the following pathways:

Antennas and Microwaves: Three major field elective courses—Electrical Engineering 162A, 163A, 163C; one capstone design course from 164D or 184DA/184DB (count as one course); and one laboratory course—64L (or by petition from 194 or 199).

Integrated Circuits: Three major field elective courses from Electrical Engineering 115B, 115C, and either 132B or 163A; one capstone design course from 115D or 184DA/184DB (count as one course); and one laboratory course—115BL (or by petition from 194 or 199).

Microelectromechanical (MEMS) Systems: Three major field elective courses from Electrical Engineering 115B or 123A, 128 or 163A, and CM150; one capstone design course—129D; and one laboratory course from 122L or CM150L (or by petition from 194 or 199).

Photonics and Plasma Electronics: Three major field elective courses from Electrical Engineering 170A, 170B, and 174 or M185; one capstone design course—173D; and one laboratory course—170L (or by petition from 194 or 199).

Signals and Systems: Three major field elective courses from Electrical Engineering 114, 115B, 131B, 132B, 136, 142, 162A; one capstone design course from 113D, 173D, 180D, 181D, or 184DA/184DB (count as one course); and one laboratory course from 115BL or M116L or M171L (or by petition from 194 or 199).

Solid State: Three major field elective courses—Electrical Engineering 123A, 123B, 128; one capstone design course—129D; and one laboratory course—22L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ges/.

Biomedical Engineering Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL; Computer Science
31; Electrical Engineering 2, 3, 10, M16 (or Computer Science M51A); Life Sciences 2, 3, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Electrical Engineering 101A, 102, 103, 110, 110L, 113, 115A, 115AL, 131A, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 units) selected from the biomedical engineering pathway as follows: three major field elective courses from Bioengineering CM186, Electrical Engineering 114, 132A, 141, and either Electrical Engineering 176 or Mechanical and Aerospace Engineering 105A; one capstone design course from Electrical Engineering 113D or 180D; and one laboratory course from Bioengineering CM187 or Electrical Engineering M171L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Computer Engineering Option

Preparation for the Major

Required: Chemistry and Biochemistry 20A; Computer Science 31, 32, 33, 35L; Electrical Engineering 2, 3, 10, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Electrical Engineering 101A, 102, 103, 110, 110L, 113, 115A, 115C, M116C (or Computer Science M151B), 131A, 132B or Computer Science 118, Mathematics 132, Statistics 105; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and three major field elective courses (12 units), one design course (4 units), and one laboratory course (2 to 4 units) selected from the computer engineering pathway as follows: three major field elective courses from Computer Science 111, M117 (or Electrical Engineering 132A), and either 131 or 132 or 180; one capstone design course from Electrical Engineering 113D, 180D, 181D, or 184DA/184DB (count as one course); and one laboratory course—Electrical Engineering M116L (or by petition from 194 or 199).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program. 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.

Areas of Study

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed below for the thesis (seven courses) and non-thesis (eight courses) options. The selected courses must be approved by the faculty adviser.

Course Requirements

Students may select either the thesis plan or the non-thesis (comprehensive examination) plan. The selection of courses is tailored to the professional objectives of the students and must meet the requirements stated below. The courses should be selected and approved in consultation with the faculty adviser. Departures from the stated requirements are considered only in exceptional cases and must be approved by the departmental graduate adviser.

The minimum requirements for the M.S. degree are as follows:

1. Requisite. B.S. degree in Electrical Engineering or a related field.

2. All M.S. program requirements should be completed within two academic years from admission into the M.S. graduate program in the Henry Samueli School of Engineering and Applied Science.

3. Students must maintain a minimum cumulative grade-point average of 3.0 every term and 3.0 in all graduate courses.
4. **Thesis Option.** Students selecting the thesis option must complete at least the following requirements: (a) five formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) two Electrical Engineering 598 courses involving work on the M.S. thesis, (e) no other 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, and (f) an M.S. thesis completed under the direction of the faculty adviser to a standard that is approved by a committee comprised of three faculty members. The thesis research must be conducted concurrently with the coursework.

5. **Non-Thesis Option.** Students selecting the non-thesis option must complete at least the following requirements: (a) six formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical Engineering 297, (d) Electrical Engineering 299 to serve as the M.S. comprehensive examination, which is evaluated by a committee of three faculty members appointed by the department. In case of failure, students may be reexamined only once with consent of the departmental graduate adviser, and (e) no 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements.

6. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed above for the thesis (seven courses) and non-thesis (eight courses) options. The selection of the major and minor sequences of courses must be from different established tracks, or approved ad hoc tracks, or combinations thereof. The selected courses must be approved by the faculty adviser.

7. For the thesis option at least four, and for the non-thesis option five, of the formal graduate courses used to satisfy the M.S. program requirements listed above must be in the Electrical Engineering Department.

8. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses.

9. At most one upper division undergraduate course is allowed to replace one of the formal graduate courses covering the major and minor fields of study provided that (a) the undergraduate course is not required of undergraduate students in the Electrical Engineering Department and (b) the undergraduate course is approved by the faculty adviser.

10. A track is a coherent set of courses in some general field of study. The department suggests lists of established tracks as a means to assist students in selecting their courses. Students are not required to adhere to the suggested courses in any specific track.

### Circuits and Embedded Systems Area Tracks

1. **Embedded Computing Track.** Courses deal with the engineering of computer systems as may be applied to embedded devices used for communications, multimedia, or other such restricted purposes. Courses include Computer Science 251A, Electrical Engineering 201A, 201C, M202A, M202B, 213A, M216A.

2. **Integrated Circuits Track.** Courses deal with the analysis and design of analog and digital integrated circuits; architecture and integrated circuit implementations of large-scale digital processors for communications and signal processing; hardware-software co-design; and computer-aided design methodologies. Courses include Computer Science 251A, 252A, Electrical Engineering 213A, 215A through 215E, M216A, 221A, 221B.

### Physical and Wave Electronics Area Tracks

1. **Electromagnetics Track.** Courses deal with electromagnetic theory; propagation and scattering; antenna theory and design; microwave and millimeter wave circuits; printed circuit antennas; integrated and fiber optics; microwave-optical interaction, antenna measurement, and diagnostics; numerical and asymptotic techniques; satellite and personal communication antennas; periodic structures; genetic algorithms; and optimization techniques. Courses include Electrical Engineering 221C, 260A, 260B, 261, 262, 263, 266, 270.


3. **Solid-State and Microelectromechanical Systems (MEMS) Devices Track.** Courses deal with solid-state physical electronics, semiconductor device physics and design, and microelectromechanical systems (MEMS) design and fabrication. Courses include Electrical Engineering 221A, 221B, 221C, 222, 223, 225, CM250A, M250B, Mechanical and Aerospace Engineering 281, 284, C287L.

### Signals and Systems Area Tracks

1. **Communications Systems Track.** Courses deal with communication and telecommunication principles and engineering applications; channel and source coding; spread spectrum communication; cryptography; estimation and detection; algorithms and processing in communication and radar; satellite communication systems; stochastic modeling in telecommunication engineering; mobile radio engineering; and telecommunication switching, queuing system, communication networks, local-area, metropolitan-area, and wide-area computer communication networks. Courses include Electrical Engineering 205A, 210A, 230A through 230D, 231A, 231E, 232A through 232E, 233, 238, 241A.

2. **Control Systems and Optimization Track.** Courses deal with state-space theory of linear systems; optimal control of deterministic linear and nonlinear systems; stochastic control; Kalman filtering; stability theory of linear and nonlinear feedback control systems; computer-aided design of control systems; optimization theory, including linear and nonlinear programming; convex optimization and engineering applications; numerical methods; nonconvex programming; associated network flow and graph problems; renewal theory; Markov chains; stochastic dynamic programming; and queuing theory. Courses include Electrical Engineering 205A, 208A, M208B, M208C, 210B, 236A, 236B, 236C, M237, M240A, 240B, M240C, 241A, 241C, M242A, 243.

3. **Signal Processing Track.** Courses deal with digital signal processing theory, statistical signal processing, analysis and design of digital filters, digital speech processing, digital image processing, multi-

Ad Hoc Tracks
In consultation with their faculty advisers, students may petition for an ad hoc track tailored to their professional objectives. This may comprise graduate courses from established tracks, from across areas, and even from outside electrical engineering. The petition must justify how the selection of courses in the ad hoc track forms a coherent set of courses, and how the proposed ad hoc track serves the professional objectives. The petition must be approved by the faculty adviser and the departmental graduate adviser.

Comprehensive Examination Plan
The M.S. comprehensive examination requirement is satisfied either (1) by solving a comprehensive examination problem in the final project, or equivalent, of every formal graduate electrical engineering course taken. A grade-point average of at least 3.0 in the comprehensive examination problems is required for graduation. The M.S. individual study program is administered by the academic adviser, the director of the area to which the students belong, and the vice chair of Graduate Affairs or (2) through completion of an individual study course (Electrical Engineering 299) under the direction of a faculty member. Students are assigned a topic of individual study by the faculty member. The study culminates with a written report and an oral presentation. The M.S. individual study program is administered by the faculty member directing the course, the director of the area to which the students belong, and the vice chair of Graduate Affairs. Students who fail the examination may be reexamined once with consent of the vice chair of Graduate Affairs.

Electrical Engineering Ph.D.
Areas of Study
Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectro-

6. At least two of the formal graduate courses must be in electrical engineering
7. Within two academic years from admission into the Ph.D. program, all courses should be completed and the Ph.D. preliminary examination should be passed. It is strongly recommended that students take the Ph.D. preliminary examination during their first academic year in the program
8. The University Oral Qualifying Examination must be taken when all required courses are complete, and within one year after passing the Ph.D. preliminary examination
9. Students admitted originally to the M.S. program in the Electrical Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination
10. Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus

Written and Oral Qualifying Examinations
The written qualifying examination is known as the Ph.D. preliminary examination in the department. The purpose of the examination is to assess student competency in the discipline, knowledge of the fundamentals, and potential for independent research. Students admitted originally to the M.S. program in the Electrical Engineering Department must complete all M.S. program requirements with a grade-point average of at least 3.5 to be considered for admission into the Ph.D. program. Only after admission into the program can students take the Ph.D. preliminary examination, which is held once every year. Students are examined independently by a group of faculty members in their general area of study. The examination by each faculty member typically includes both oral and written components, and students pass the entire Ph.D. preliminary examination and not in parts. Students who fail the examination may repeat it once only with consent of the departmental graduate adviser. The preliminary examination, together with the course
requirements for the Ph.D. program, should be completed within two years from admission into the program.

After passing the written qualifying examination described above, students are ready 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 preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus.

Facilities and Programs

Computing Resources

Students and faculty have access to a modern networked computing environment that interconnects UNIX workstations as well as Windows and Linux PCs. These machines are provided by the Electrical Engineering Department; most of them operate in a client-server mode, but stand-alone configurations are supported as well. Furthermore, this network connects to mainframes and supercomputers provided by the Henry Samueli School of Engineering and Applied Science and the Office of Academic Computing, as well as off-campus supercomputers according to need.

The rapidly growing department-wide network comprises about 500 computers. These include about 200 workstations from Sun, HP, and SGI, and about 300 PCs, all connected to a 100 Mbit/s network with multiple parallel T3 lines running to individual research laboratories and computer rooms. The server functions are performed by several high-speed, high-capacity RAID servers from Network Appliance and IBM which serve user directories and software applications in a unified transparent fashion. All this computing power is distributed in research laboratories, computer classrooms, and open-access computer rooms.

Research Centers and Laboratories

Center for High-Frequency Electronics

The Center for High-Frequency Electronics has been established with support from several governmental agencies and contributions from local industries, beginning with a $10 million grant from Hewlett-Packard.

The first major goal of the center is to combine, in a synergistic manner, five areas of research. These include (1) solid-state millimeter wave devices, (2) millimeter systems for imaging and communications, (3) millimeter wave high-power sources (gyrotrons), (4) GaAs gigabit logic systems, and (5) VLSI and LSI based on new materials and structures. The center supports work in these areas by providing the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations into new electronic devices. Students, both graduate and undergraduate, receive training and instruction in a unique facility.

The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different interdependent fields. The Electrical Engineering Department, other departments within UCLA, and local universities (such as Caltech and USC) have begun to combine and correlate certain research programs as a result of the formation of the center.

Clean Energy Research Center–Los Angeles

The Clean Energy Research Center–Los Angeles (CERC-LA) was created by UCLA to tackle many of the grand challenges related to generation, transmission, storage, and management of energy. As many energy challenges are global in nature, this new center will engage the participation of a multidisciplinary group of researchers from many nations. The director of this new center is professor Lei He. CERC-LA leads a U.S.-China clean energy and climate change research consortium. CERC-LA, together with the China National Center for Climate Change Strategy and International Cooperation (NCSC), Peking University (PKU), and Fudan University, was selected by the U.S. Department of State and the China National Development and Reform Commission as a U.S.-China EcoPartner. CERC-LA plans to have satellite offices in other cities including Shanghai and Beijing.

Circuits Laboratories

The Circuits Laboratories are equipped for measurements on high-speed analog and digital circuits and are used for the experimental study of communication, signal processing, and instrumentation systems. A hybrid integrated circuit facility is available for rapid mounting, testing, and revision of miniature circuits. These include both discrete components and integrated circuit chips. The laboratory is available to advanced undergraduate and graduate students through faculty sponsorship on thesis topics, research grants, or special studies.

Electromagnetics Laboratories

The Electromagnetics Laboratories involve the disciplines of microwaves, millimeter waves, wireless electronics, and electromechanics. Students enrolled in microwave laboratory courses, such as Electrical Engineering 164D and 164L, special projects classes such as Electrical Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: (1) integrated microwave circuits and antennas, (2) integrated millimeter wave circuits and antennas, (3) numerical visualization of electromagnetic waves, (4) electromagnetic scattering and radar cross-section measurements, and (5) antenna near field and diagnostics measurements.

Nanoelectronics Research Facility

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

Photonics and Optoelectronics Laboratories

In the Laser Laboratory students study the properties of lasers and gain an understanding of the application of this modern technology to optics, communication, and holography. The Photonics and Optoelectronics Laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrafast lasers, parametric frequency conversion, electro-optics, infra-
red detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al2O3 lasers, ultraviolet and visible wavelength argon lasers, wavelength-tunable dye lasers, as well as gallium arsenide, helium-neon, excimer, and high-powered continuous and pulsed carbon dioxide laser systems. Also available are equipment and facilities for research on semiconductor lasers, fiber optics, nonlinear optics, and ultrashort laser pulses. Facilities for mirror polishing and coating and high-vacuum gas handling systems are also available. These laboratories are open to undergraduate and graduate students who have faculty sponsorship for their thesis projects or special studies.

**Plasma Electronics Facilities**

Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art table top terawatt (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 multi-channel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing. The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focusable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS; other equipment includes a theta-pinch plasma generator, an electron linac injector, and electron detectors and analyzers. A second group of laboratories is dedicated to basic research in plasma sources for basic experiments, plasma processing, and plasma heating.

There is also a large computing cluster called DAWSON 2 that is dedicated to the study of plasma-based acceleration, inertial fusion energy, and high energy density plasma science. DAWSON 2 consists of 96 HP L390 nodes each with 12 Intel X5650 CPUs and 48 GB of RAM, and 3 Nvidia M2070s GPUs and 18 GB of Global Memory (for a total of 1152 CPUs and 288 GPUs) connected by a non-blocking QDR Infiniband network with 160TB of parallel storage from Panasas. The system’s peak performance is approximately 300TF/150TF (single/double precision) and it has a measured linpack performance of 68.1TF (double precision). DAWSON 2 is housed within the UCLA Institute for Digital Research Engineering data center.

**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.

**Multidisciplinary Research Facilities**

The department is also associated with several multidisciplinary research centers including:

- California NanoSystems Institute (CNSI)
- Center for Embedded Networked Sensing (CENS)
- Center for High-Frequency Electronics (CHFE)
- Center for Nanoscience Innovation for Defense (CNID)
- Functional Engineered Nano Architectonics Focus Center (FENA)
- Plasma Science and Technology Institute
- UCLA Wireless Health Institute
- Western Institute for Nanoelectronics (WIN)

**Faculty Groups and Laboratories**

Department faculty members also lead a broad range of research groups and laboratories that cover a wide spectrum of specialties, including:

- Actuated Sensing and Coordinated Embedded Networked Technologies (ASCENT) Laboratory (Kaiser)
- Adaptive Systems Laboratory (Sayed)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomous Intelligent Networked Systems (Rubin)
- BioPhotonics Laboratory (Ozcan)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Razavi)
- Complex Networks Group (Roychowdhury)
- Cyber-Physical Systems Laboratory (Tabuada)
- Device Research Laboratory (K. Wang)
- Digital Microwave Laboratory (E. Wang)
- Energy and Electronic Design Automation Laboratory (He)
- Flutter Systems Research Laboratory (Balakrishnan)
- High-Performance Mixed Mode Circuit Design Group (Yang)
- High-Speed Electronics Laboratory (Chang)
- Image Communications Laboratory (Villasenor)
- Information Theory and Systems Laboratory (Diggavi)
- Integrated Circuits and Systems Laboratory (Abidi)
- Laser-Plasma Group (Joshi)
- Microwave Electronics Laboratory (Itoh)
- Millimeter Wave and Optoelectronics Laboratory (Fetterman)
- Nanoelectronics Research Center (Candler, Franz)
- Nanostructure Devices and Technology Laboratory (Chui)
- Nanosystems Computer-Aided Design Laboratory (Gupta)
- Networked and Embedded Systems Laboratory (Srivastava)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonovitch)
- Proactive Medianet Laboratory (van der Schaar)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Electronics Laboratory (Stafsudd)
- Sensors and Technology Laboratory (Candler)
- Speech Processing and Auditory Perception Laboratory (Roychowdhury)
- Terahertz Devices and Intersubband Nanostructures Group (Williams)
- Wireless Integrated Systems Research Group (Daneshrad)
Faculty Areas of Thesis Guidance

Professors

Asad A. Abidi, Ph.D. (UC Berkeley, 1981)
High-performance analog electronics, device modelling

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

Katsushi Arisaka, Ph.D. (U. Tokyo, Japan, 1985)
High energy and astro-particle experiments

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

Panagiotsi D. Christofides, Ph.D. (Minnesota, 1990)
Process modeling, dynamics and control, computational and applied mathematics

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

Babak Daneshrad, Ph.D. (UCLA, 1993)
Digital VLSI circuits: wireless communication systems, high-performance communications integrated circuits for wireless applications

Suhas Diggavi, Ph.D. (Stanford, 1999)
Wireless communication, information theory, wireless networks, data compression, signal processing

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

Wen-S. Grundt, M.D., FACS (Columbia, 1980)
Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopes, spectroscopy, photodynamic therapy (PDT), optical technology, biological feedback control mechanisms

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 modeling and design, power-efficient computer architectures and systems, numerical and combinatorial optimization

Diana L. Huffaker, Ph.D. (Texas, Austin, 1995)
Solid-state nanotechnology, MWIR optoelectronic devices, solar cells, Si photonics, novel materials

Tatsuo Hoh, 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

Bahram Jalali, Ph.D. (Columbia, 1989)
RF photonics, integrated optics, fiber optic integrated circuits

Laser fusion, laser acceleration of particles, nonlinear optics, high-power lasers, plasma physics

William J. Kaiser, Ph.D. (Wayne State, 1983)
Research and development of new microsensor and microinstrument technology for industry, science, and biomedical applications;

development and applications of new atomic-resolution scanning probe microscopy methods for microelectronic device research

Alan Laub, Ph.D. (Minnesota, 1974)
Numerical linear algebra, numerical analysis, condition estimation, computer-aided control system design, high-performance computing

Kuo-Nan Liu, Ph.D. (New York U., 1971)
Radiative transfer, remote sensor of clouds and aerosols and climate/clouds-aerosols research

Jing-Sheng Jason Cong, Ph.D. (Illinois, Urbana, 1990)
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 interaction, advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics

Scientific computing, applied mathematics

C. Kumar N. Patel, Ph.D. (Stanford, 1961)
Quantum electronics: nonlinear 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 U., Canada, 1988)
Communication systems and theory with applications to wireless sensor networks

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

W. Roy Chowdhury, Ph.D. (Stanford, 1989)
Models of communication and distributed processing systems, quantum computation and information processing, circuits and computing paradigms for nano-electronics and molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory

Izhak Rubin, Ph.D. (Princeton, 1970)
Telecommunications and computer communications systems and networks, mobile wireless networks, multimedia IP networks, UAV/UGV-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering

Henry Samueli, Ph.D. (UCLA, 1980)
VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design

Ali H. Sayed, Ph.D. (Stanford, 1992)
Adaptive systems, stochastic 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

Stefano Soatto, Ph.D. (Caltech, 1996)
Computer vision, systems and control theory, detection and estimation, robotics, system identification, shape analysis, motion analysis, image processing, video processing, autonomous systems

Jason L. Speyer, Ph.D. (Harvard, 1968)
Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Mani B. Srivastava, Ph.D. (UC Berkeley, 1992)
Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems

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

Paulo Tabuada, Ph.D. (Technical U. Lisbon, Portugal, 2002)
Real-time, networked, embedded control systems; mathematical systems theory including discrete-event, timed, and hybrid systems; geometric nonlinear control; algebraic/categorical methods

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

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

Mihaila van der Schaar, Ph.D. (Eindhoven U. of Technology, Netherlands, 2001)
Multimedia processing and compression, multi-media networking, multimedia communications, multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing

John D. Villasenor, Ph.D. (Stanford, 1989)
Communications, signal and image processing, configurable computing systems, and design environments

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoelectronics and optoelectronics, nano and molecular devices, MEMS and superlattices, microwave and millimeter electronics, quantum information

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

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

A.V. Balakrishnan, Ph.D. (USC, 1954)†
Nonlinear optics, ultrafast optics, laser chaos, semiconductor lasers, optoelectronics, photonics, nonlinear and ultrafast processes

Francis C. Chen, Ph.D. (Harvard, 1964)
Radio frequency plasma sources and diagnostics for semiconductor processing

* Also Professor of Physics

† Also Professor Emeritus of Mathematics
Harold R. Fettermen, 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

Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)
Operations research, mathematical programming, computer programming, applications of mathematical programming to engineering and economic systems

Rajeev Jain, Ph.D. (Katholieke U., Leuven, Belgium, 1985)
Design of digital communications and digital signal processing circuits and systems

Nhan N. Levan, Ph.D. (Monash U., Australia, 1966)
Control systems, stability and stabilization, errors in dynamic systems, signal analysis, waveforms, theory and applications

Dee-Son Pan, Ph.D. (Caltech, 1977)
New semiconductor devices for millimeter and RF power generation and amplification, transport in small geometry semiconductor devices, generic device modeling

Frederick W. Schott, Ph.D. (Stanford, 1949)

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

Jack Willis, B.S.U. (London, 1945)
Active circuits, electronic systems

Alan N. Willson, Jr., Ph.D. (Syracuse, 1967)
Theory and application of digital signal processing including VLSI implementations, digital filter design, nonlinear circuit theory

Donald M. Wiberg, Ph.D. (Caltech, 1965)
Nanoelectronic and optoelectronic devices and technology, heterostructure semiconductor devices, monolithic integration of heterogeneaus technology, exploratory nanotechnology

Christina Fragouli, Ph.D. (UCLA, 2000)
Network information flow theory and algorithms network coding, connections between communications and computer science

Puneet Gupta, Ph.D. (UC San Diego, 2007)
CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing

Mark H. Hansen, Ph.D. (UC Berkeley, 1994)
Estimation and inference, statistical learning, data analysis; model selection, nonparametric methods; visualization and information design

Mona Jarrahi, Ph.D. (Stanford, 2007)
Radical frequency-domain, microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonics and optoelectronics

Dejan S. Karkovic, Ph.D. (UC Berkeley, 2006)
Power-area-efficient digital integrated circuits, VLSI architectures for wireless communications, organization methods and supporting CAD flows

Aydogan Ozcan, Ph.D. (Stanford, 2009)
Biomaterials, nanophotonics, nonlinear optics, nanohar-pakari, HF (UC San Diego, 2003)
Mixed-signal IC design, signal processing and communication

Yuanwen 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

Benjamin Williams, Ph.D. (MIT, 2003)
Development of terahertz quantum cascade lasers

Assistant Professors

Daniela Cabric, Ph.D. (UC Berkeley, 2007)
Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and digital communication algorithms, performance analysis and experiments on embedded system platforms

Robert N. Candler, Ph.D. (Stanford, 2006)
MEMS and nanoscale devices, fundamental limitations of sensors, packaging, biological and chemical sensing

Lara Dolecek, Ph.D. (UC Berkeley, 2007)
Information and coding theory; graphical models, statistical algorithms and computational methods with applications to large-scale and complex systems for data processing, communication and storage

Florian Dörfler, Ph.D. (UC Santa Barbara, 2013)
Synchronization in complex oscillator networks and power grids; control, monitoring, and security in cyber-physical systems and smart power grids; cooperative control and coordination in autonomous multi-agent systems

Adjunct Professors

Enzo Biglieri, Dr. Ing. (Politecnico di Torino, Italy, 1967)
Digital communication, wireless channels, modulation, error-control coding, signal processing in telecommunications

Dariush Divsalar, Ph.D. (UCLA, 1978)
Information theory; communication theory, bandwidth-efficient combined coding modulation techniques, spread spectrum systems and mutual user interference for CDMA, turbo codes, binary and nonbinary LDPC codes, iterative decoding

Mary Eshaghan-Wilner, Ph.D. (USC, 1998)
Nanoscale architectures, bioinformatics network, heterogeneous computing, mapping and scheduling paradigms, optical interconnects, VLSI and reconfigurable chips, parallel algorithms for image processing

Asad M. Madni, Ph.D. (California Coast U., 1987)
Development and commercialization of intelligent sensors and systems, RF and microwave instrumentation, signal processing

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

Ingrid M. Verbauwhede, Ph.D. (Katholieke U., Leuven, Belgium, 1991)
Embedded systems, VLSI, architecture and circuit design and design methodologies for applications in security, wireless communications and signal processing

El Yahoumich, Ph.D. (Harvard, 1972)
Optoelectronics, high-speed optical communication, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication

Adjunct Associate Professor

Keisuke Goda, Ph.D. (MIT, 2007)
Biophotonics, imaging, fiber-optic communication

Adjoint Assistant Professor

Jin Hyung Lee, Ph.D. (Stanford, 2004)
Advanced imaging techniques for biomedical applications; neuroscience and neural-engineering; magnetic resonance imaging (MRI); development of novel image contrast strategies; alternate image acquisition, reconstruction, and processing techniques

Lower Division Courses

2. Physics for Electrical Engineers. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Physics 1C. Introduction to concepts of modern physics necessary to understand solid-state devices, including elementary quantum theory, fundamental energies, electrons in solids. Discussion of electrical properties of semiconductors leading to operation of junction devices. Letter grading.

3. Introduction to Electrical Engineering. (3) Lecture, two hours; lab, one hour; outside study, five hours. Requisite: Physics 1B. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunications, electrical grid, automatic computing and control, and enabling device technology. Research frontiers of electrical engineering. Introduction to measurement and design of electrical circuits. 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

100. Electrical and Electronic Circuits. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisites: Mathematics 33A, 33B, Physics 1C. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state circuit behavior, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.

101A. Engineering Electromagnetics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mathematics 32A and 32B, or 33A and 33B, Physics 1C. Electromagnetic field concepts, waves and phasors, transmission lines and Smith chart, transient re-
101B. Electromagnetic Waves. (4) (formerly numbered 161.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Time-varying fields and waves, propagation, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radi- ation and antennas. Letter grading.

Mr. Y.E. Wang (W,Sp)


Ms. Cabric, Ms. Fragouli (F,Sp)

103. Applied Numerical Computing. (4) Lecture, four hours; laboratory, four hours; outside study, seven hours. Requisites: Civil Engineering 15 or Computer Science 31, Mathematics 33A, 33B (33B may be taken concurrently). Introduction to numerical computing and analysis. Floating point representation and round-off error; numerical methods for systems of linear equations; methods for systems of nonlinear equations. Introduction to numerical optimization, linear programming, least squares, interpolation, numerical integration, and differential equations. Letter grading.

Ms. Dolecek, Mr. Vandenberge (F,Sp)

110. Circuit Analysis I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 10. Corequisite: course 102. Sinusoidal excitation and phasors, AC steady state analysis, AC steady state power, network functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis. Letter grading.

Mr. Abidi, Mr. Willson (F,Sp)

110L. Circuit Measurements Laboratory. (2) Laboratory, four hours; outside study, two hours. Requisite: course 100 or 110. Experiments with basic circuits containing resistors, capacitors, inductors, and op-amps. Ohm’s law voltage and current division. Thevenin and Norton equivalent circuits, superposition, transient and steady state analysis, and frequency response principles. Letter grading.

Mr. Razavi (F,W,Sp)


Mr. Dzhanidze (F,Sp)

113D. Digital Signal Processing Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 113. Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments involving A/D and D/A conversion, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for communications, speech, audio, or video using DSP chip. Letter grading.

Mr. Briggs (Sp)

114. Speech and Image Processing Systems Design. (4) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Enforced requisite: course 113. Design tools, techniques, and implementation of speech and image processing systems. Speech pro- duction, analysis, and modeling in first half of course; design techniques for image enhancement, filtering, and transformation in second half. Lectures supplemented by laboratory implementation of speech and image processing tasks. Letter grading.

Mr. Villasenor (W)

115A. Analog Electronic Circuits I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Frequency response of operational amplifier and op-amp circuits, operational amplifier systems. Analysis and design of single-stage amplifiers. DC biasing circuits. Small-signal analysis. Operational amplifier systems. Letter grading.

Mr. Daneshzar, Mr. Parmar (F,Sp)

115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. Enforced requisite: courses 110L, 115A. Experimental determination of device characteristics, resistive diode circuits, single-stage amplifiers, compound transistor stages, feedback of on single-stage amplifiers, operational amplifiers, and operational amplifier circuits. Introduction to hands-on design experience based on individual student hardware design and implementation platforms. Letter grading.

Mr. Razavi (F,W)


Mr. Razavi (W)

115B. Analog Electronics Laboratory II. (4) Laboratory, four hours; outside study, eight hours. Enforced requisite: course 115B. Recommended coreq- uisite: course 115D. Study of high-frequency effects in discrete circuit design. Laboratory experiments include transmission lines, tuned amplifiers, oscillators, mixers, and broadband amplifiers. Hands-on experience in construction of surface-mount circuits and their characterization. Letter grading.

Mr. Razavi (F,Sp)

115C. Digital Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115A. Computer Science M51A. Recommended: course 115B. Tran- sistor-level digital circuit analysis and design. Modern logic families (static CMOS, pass-transistor, dynamic logic), integrated circuit (IC) layout, digital circuits (logic design, memory, logic families, time, etc.), computer-aided simulation of digital circuits. Letter grading.

Ms. Cabric, Mr. Yang (W,Sp)

115D. Design Studies in Electronic Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115D. Computer Science M51A. Recommended: course 115B. Exploration of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using programmed ar- ray logic, design projects. Letter grading.

Mr. He (F,Sp)

M117. Computer Networks: Physical Layer. (4) (Same as Computer Science M117.) Lecture, two hours; discussion, two hours; outside study, six hours. Enforced requisite: course 117. Introduction to fundamental computer communication concepts underlying and supporting modern networks, with focus on wireless communications and media access layers of network protocol stack. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environment awareness, and experimental laboratory sessions included. Letter grading.

Mr. Dzhanidze (F,Sp)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: courses 2, 121B. Element of devices such as analysis of dynamics, variability, and personal applications such as wireless health, positioning, and environment awareness, and experimental laboratory sessions included. Letter grading.

Mr. He (F,Sp)

121L. Semiconductor Device Design Laboratory. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 2, 121B (may be taken concurrently). Series of experiments conducted to enable students to gain hands-on experience and better understanding of semiconductor transport parameters and semiconductor device characteristics to see interplay between various device performance metrics. Letter grading.

Mr. Dzhanidze (F,Sp)

122L. Semiconductor Devices Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisite: courses 2, 121B (may be taken concurrently). Design fabrication and characterization of n-p junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Letter grading. Mr. Candler (W)

123A. Fundamentals of Solid-State I. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 2 or Physics 1C. Limitations of senior engineering materials and introduction to modeling 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. Huffer (F)

123B. Fundamentals of Solid-State II. (4) Lecture, three hours; outside study, nine hours. Enforced requisite: course 123A. Discussion of solid-state proper- ties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading.

Ms. Huffer (W)

128. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Enforced requisite: Physics 1C. Introduction to funda- mentals of nanoscience for electronics nanosystems. Principles of fundamental quantities: electron charge, effective mass, Bohr magneton, and spin, as well as theoretical approaches. From these nanoscale components, discussion of basic behaviors of nanosys- tems such as analysis of dynamics, variability, and noise, contrasted with those of scaled CMOSs. Incorporation of design project in which students are chal- lenged to design electronics nanosystems. Letter grading.

Mr. K.-L. Wang (Sp)

M129. Semiconductor Processing and Device Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 121B. Introduction to CAD tools used in integrated circuit processing and device design. Device struc- ture design and simulation tools are introduced. Process integration tool is based on SUPREM. Course famili-
iates students with those tools. Using CAD tools, CMOS process integration to be designed. Letter grading. Letter grading.

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, probability spaces, expected values, distribution functions, 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, Mr. Yao (FW)

131B. Introduction to Stochastic Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced 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 (Not offered 2013–14)


132B. Data Communications and Telecommunication Networks. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. Layered communications architectures. Queueing system modeling and analysis. Error control, flow and congestion control. Packet switching, circuit switching, and routing. Network performance analysis and design. Multiple-access communications: TDMA, FDMA, polling, random access. Local, metropolitan, wide area, integrated services networks. Letter grading. Mr. Rubin (F)


141. Principles of Feedback Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 102. Mathematical modeling of physical control systems in terms of differential equations and transfer functions. Design problems, system performance indices of feedback control systems via classical techniques, root-locus and frequency-domain methods. Computer-aided solution of design problems from real world. Letter grading. Mr. Levan, Mr. Tabuada (W,SP)

142. Linear Systems: State-Space Approach. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced 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 (W)

CM150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Bioengineering CM150 and Mechanical and Aerospace Engineering CM180.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to micromachining technologies and microelectromechanical systems (MEMS). Methods of micromachining and how these methods can be used to produce various micro- and nanometer- sized micro-structures, microsensors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250A. Letter grading.

150DL. Photonic Sensor Design Laboratory. (4) Lecture, two hours; laboratory, four hours; discussion, one hour; outside study, eight hours. Limited to seniors. Multidisciplinary course with lectures and labs on performance of optical devices, sensors, optical instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations on experiments on transduction, measurement, alignment, and sensing. Letter grading. Mr. Liu (W)

150L. Microwave Wireless Laboratory. (2) (Same as Bioengineering CM150L and Mechanical and Aerospace Engineering CM180L.) Lecture, one hour; laboratory, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course CM150, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of micro- and nanometer-sized micro-structures, microsensors, and microactuators. Students design and implement microfabrication processes and devices. Letter grading. Mr. Chui, Mr. Candler (F)

152A. Wireless Communication Links and Antennas. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 161B. Analysis of transmitting and receiving antennas and antenna arrays. Array synthesis. Adaptive arrays. Friis transmission formula, radar equations. Cell-site and mobile antennas, bandwidth budget. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Rahmat-Samii (SP)

163A. Introductory Microwave Circuits. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Transmission lines: series and parallel impedances, matching networks, transmission lines, antennas, atmosphere, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Y.E. Wang (F)

163C. Introduction to Microwave Systems. (4) Lecture, four hours; discussion, outside study, seven hours. Enforced requisite: course 101B. Theory and design of modern microwave systems such as satellite communication systems, radar systems, wireless sensors, and biological applications of microwaves. Letter grading. Mr. Y.E. Wang (W)

164D. Microwave Wireless Design. (4) Lecture, one hour; laboratory, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101B. Microwave integrated circuit design from wireless system perspective, with focus on (1) use of microwave circuit simulation tools, (2) design of microwave front end systems, (3) design of microwave front end systems, (4) development of reliable power amplifier, (5) knowledge and skills required in wireless integrated circuit characterization and implementation. Letter grading. Mr. Chang (SP)

164L. Microwave Wireless Laboratory. (2) Lecture, one hour; laboratory, three hours; outside study, three hours. Enforced requisite: course 101B. Measurement techniques and instrumentation for active and passive microwave components; cavity resonators, waveguides, transmission lines, and directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip and coaxial systems. Letter grading. Mr. Itoh (W)

170A. Principles of Photonics. (4) Lecture, four hours; discussion, outside study, seven hours. Enforced requisites: courses 2, 101A. Development of solid foundation on essential principles of photonics from ground up with minimum prior knowledge on this subject. Topics include optical properties of materials, photodetectors, optical interferometers and resonators, optical coupling and modulation, absorption and emission, principles of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (F)

170C. Photonic Sensors and Solar Cells. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 101A. Recommended: courses 2, 170A. Fundamentals of detection of light for communication and sensing, as well as conversion of light to electrical energy in solar cells. Introduction to radiometry, semiconductor photodetectors, noise processes and figures of merit, thermal detectors, and fiber optics. Photosensitive devices of various types and materials. Letter grading. Mr. Liu (SP)

170L. Laser Laboratory. (4) (Formerly numbered 172L.) Lecture, four hours; discussion, eight hours. Enforced requisite: course 101B. Properties of lasers, including saturation, gain, mode structure. Laser applications, including optics, modulation, communication, holography, and interferometry. Letter grading. Mr. Reddy (Sp)

170D. Photonics and Communication Design. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101B. Recommended: course 132A. Introduction to measurement of basic photonic devices, including LEDs, laser diodes, and optical detectors. Properties of lasers, including saturation, gain, mode structure. Laser applications, including optics, modulation, communication, holography, and interferometry. Letter grading. Mr. Reddy (Sp)

170D. Photonics and Communication Design. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101B. Recommended: course 132A. Introduction to measurement of basic photonic devices, including LEDs, laser diodes, and optical detectors. Properties of lasers, including saturation, gain, mode structure. Laser applications, including optics, modulation, communication, holography, and interferometry. Letter grading. Mr. Reddy (Sp)

174. Semiconductor Optoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 170A. Introduction to semiconductor optoelectronic devices for optical communications, interconnects, and signal processing. Basic optical properties of semiconductors, p-n junctions, laser diodes, avalanche photodiode detectors, and optical amplifiers. Letter grading. Mr. Ozcan (SP)

176. Photonics in Biomedical Applications. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101B. Study of different types of optical systems and their photonics components that play a role in current and projected biomedical applications. Specific capabilities of photonics to be related to each example. Letter grading. Mr. Ozcan (Sp)
and signal processing subsystems. Different project to be assigned yearly in which student teams create high-performance designs that manage trade-offs among subsystems. Letter grading.

Mr. Kaiser, Mr. Pottie (FW)

181D. Robotic Systems Design. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: course M116, 110L, 110L, Computer Science M152A, Computer Science 31, 33. Recommended: courses 113, 141, Computer Science 3SL. Design of robotics systems that combine electromechanical hardware, software, mechatronic systems, and fundamental algorithms for sensing and control to expose students to basic concepts in robotics and current state of art. Lecture closely tied to laboratory where students work in teams to construct series of subsystems leading to final project. Letter grading. (Not offered 2013-14)

184DA-184DB. Independent Group Project Design. (2-3) (Formerly numbered 184D.) Laboratory, five hours; outside study, two hours. Enrollment by petition. Prerequisites: courses M16, 110, 110L. Course 184DA is enforced requisite to 184DB. Courses centered on group project that runs year long to give students intensive experience on hardware design, microcontroller programming, and project coordination. Several projects based on autonomous robots that traverse small mazes and courses offered yearly and target regional competitions. Students submit project proposals that are evaluated and approved by faculty members. Topics include sensing circuits and amplifier-based design, microcontroller programming, feedback control, actuation, and motor control. In Progress (184DA) and letter (184DB) grading. Mr. Briggs (FW) M185. Introduction to Plasma Electronics. (4) (Same as Physics M122.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course 101A or Physics 110A. Senior-level introductory course on electrodynamic of ionized gases and applications to materials processing, generation of coherent light, laser sources, and how to control these powerful, high-energy sources. Letter grading. Mr. Mori (F)

188. Special Courses in Electrical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in electrical engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Offered 2013-14)

194. Research Group Seminars: Electrical Engineering. (2 to 4) Seminar, four hours; outside study, eight hours. Requisites: courses M16 or course 110L. Designed for graduate computer science and electrical engineering students. Training in research and industry career paths in wireless devices for applications ranging from conventional wireless mobile devices to new area of wireless health. Laboratory design modules and course projects based on state-of-art embedded hardware platform. Letter grading. Mr. Kaiser (F)

20A. Matrix Analysis for Scientists and Engineers. (4) Lecture, four hours; outside study, eight hours. Preparation: linear algebra course. Designed for first-year graduate students in all branches of engineering, science, and related disciplines. Introduction to matrix theory and linear algebra, language in modern science and engineering is conducted. Review of matrices taught in undergraduate courses and introduction to graduate-level topics. Letter grading. Mr. Laub (F)


20B. Functional Analysis for Applied Mathematics and Engineering. (4) (Same as Mathematics M208A.) Lecture, four hours; outside study, eight hours. Requisite: course 20A. Preparation: computer programming experience. Prerequisite: course 113. Fundamentals of digital image processing theory and techniques. Topics include two-dimensional linear system transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading. Mr. Villasenor (F)

211A. Digital Image Processing I. (4) Lecture, three hours; laboratory, four hours; discussion, five hours. Preparation: computer programming experience. Prerequisite: course 113. Fundamentals of digital image processing theory and techniques. Topics include two-dimensional linear system transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading. Mr. Villasenor (F)
212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Fundamentals of multirate systems; polyphase representation; multistage implementations; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; parasuitary filter banks; wavelet transform and its relation to multirate filter banks. Letter grading. Mr. Wilson (Not offered 2013-14)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Requisite: course 212A. Digital filter design and optimization tools, architectures for digital signal processing circuits; integrated circuit modules for digital signal processing; programmable signal processors; CAD tools and cell libraries for application specific integrated circuit design; case studies of speech and image processing circuits. Letter grading. (Not offered 2013-14)

M214A. Digital Signal Processing. (4) (Same as Bioengineering 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 auditory and speech processing mechanisms, speech analysis/synthesis. Techniques include linear prediction, filter-bank models, and homomorphic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Ms. Alwan (W)

214B. Advanced Topics in Speech Processing. (4) Lecture, three hours; computer assignments, two hours; outside study, seven hours. Requisite: course M214A. Advanced techniques used in various speech-processing applications, with focus on speech recognition by humans and machine. Physiology and perception of human hearing. 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)

215A. Analog Integrated Circuit Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115B. Analysis and design of analog integrated circuits. MOS and bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and discrete-time circuits, bandgap reference. Letter grading. Mr. Abidi (F)


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, transistor architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading. Mr. Abidi (F)

215D. Analog Microsystem Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 215A. Analysis and design of data conversion interfaces and filters. Sampling circuits and architectures, D/A conversion techniques, A/D converter architectures, building blocks, precision techniques, discrete- and continuous-time filters. Letter grading. Mr. Razavi (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 in the implementation of electronic circuits 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. Chi (F)

M216A. Design of VLSI Circuits and Systems. (4) (Same as Computer Science M258A) Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Requisites: courses M16 or M258A and M18. Emphasis on design of VLSI systems. Topics include: introduction to CAD tools and cell libraries for application specific integrated circuit design; case studies of speech and image processing circuits. Letter grading. Mr. Markovic (F)

216B. VLSI Signal Processing. (4) Lecture, four hours; outside study, eight hours. Advanced concepts in VLSI signal processing, with emphasis on architectures, CAD tools and cell libraries. Design and application of complex integrated systems on chips. Letter grading. Mr. Markovic (F)

221A. Physics of Semiconductor Devices I. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of junction devices. Letter grading. Mr. Fong (W)

221B. Physics of Semiconductor Devices II. (4) Lecture, four hours; outside study, eight hours. Principles and design considerations of field effect devices and charge-coupled devices. Letter grading. Mr. Fong (W)

221C. Microwave Semiconductor Devices. (4) Lecture, four hours; outside study, eight hours. Physical principles and design considerations of micro-wave solid-state devices; Shockley barrier mixer diodes, IMPATT diodes, transistorized electron devices, tunnel diodes, microwave transistors. Letter grading. Mr. Chang (Sp)

222. Integrated Circuits Fabrication Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 2. Principles of integrated circuits fabrication processes, limitations of integrated circuits design. Topics include bulk crystal and epitaxial growth, thermal oxidation, diffusion, ion-implantation, chemical vapor deposition, dry etching, metalization, and passivation, and introduction to advanced process simulation tools. Letter grading. Mr. Chi (F)


225. Physics of Semiconductor Nanostructures and Devices. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Theoretical methods and physical 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. Ms. Hufkert (Sp, alternate years)

229. Seminar: Advanced Topics in Solid-State Electronics. (4) Seminar, four hours; outside study, eight hours, Requisites: courses 223, 224. Current research areas, such as radiation effects in semiconductor devices, diffusion in semiconductors, optical and microwave semiconductor devices, nonlinear optics, and electron emission. Letter grading. (Not offered 2013-14)

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 electrical and computer engineering (Section 1) or in electronic circuit theory and applications (Section 2). Students report on tutorial topic and on research topic in dissertation area. Letter or S/U grading. Credit/no credit. (Not offered 2013-14)

230A. Estimation and Detection in Communication and Radar Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 231A. Application of estimation and detection concepts in communication and radar engineering: random signal and noise characteristics by analytical and simulation methods; mean square (MS) and maximum likelihood (ML) estimations and algorithms; detection under ML, Bayes, and Neyman-Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Letter grading. Mr. Yao (F)

230B. Digital Communication Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 132A, 230A. Basic concepts of digital communication systems; representation of bandpass waveforms; signal space analysis and optimum receivers in Gaussian noise; comparison of digital modulation methods; synchronization and adaptive equalization; applications to modern communication systems. Letter grading. Mr. Karam (W)


230D. Signal Processing in Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 230C. Basic digital signal processing techniques for estimation and detection of signals in communication and radar systems. Optimization of dynamic range, quantization, and state constraints; DFT, convolution, FFT, NTT, Winograd DFT, systolic array; spectral analysis-windowing, AR, and ARMA; system applications. Letter grading. Mr. Yao (Sp)

231A. Information Theory: Channel and Source Coding. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Fundamental limits on compression and transmission of information. Topics include limits and algorithms for lossless data compression, channel capacity, rate versus distortion in lossy compression, and information theory for multiple users. Letter grading. Ms. Doelew (W)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Fundamentals of error control codes and de-
Electrical Engineering / 87

M250B. Microelectromechanical Systems (MEMS) Fabrication. (Same as Bioengineering M250B and Mechanical Engineering M287.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course CM150 or CM250A. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many typical processing operations and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/stress. Letter grading. Mr. Candler (Sp)

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

M252. Microelectromechanical Systems (MEMS) Design and Project Design. (4) (Same as Bioengineering M252 and Mechanical and Aerospace Engineering M252.) Lecture, four hours; outside study, eight hours. Introduction to MEMS design. Design methods and design aids such as micromachining processes, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. (W)

M255. Neuroengineering. (4) (Same as Bioengineering M250 and Neuroscience M206L.) Lecture, four hours; laboratory, three hours; outside study, five hours. Introduction to MSE 32A, Physics 10 or 16B. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity, electrophysiology (action potentials), local field potentials, EEG, ECOG, intracellular and extracellular recording, microelectrode technology, neural signal processing (neural signal frequency bands, filtering, spike detection, spike sorting, stimulation artifact removal, brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading. Mr. Markovic (W)

M256A-M256B-M256C. Evaluation of Research Literature in Neuroengineering. (2-2-2) (Same as Bioengineering M256A-M256B and Neuroscience M212A-M212B-M212C.) Discussion, two hours; outside study, four hours. Critical discussion and analysis of current literature related to neuroengineering research. S/U grading. Mr. Markovic (F)

M257. Nanoscience and Technology. (4) (Same as Mechanical and Aerospace Engineering M287.) Lecture, four hours; outside study, eight hours. Enforced requisite: course CM250A. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication; nanocharacterization; nanoelectronics, and nano-detection technology. Introduction to new knowledge and technologies in nanoscale areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading. Letter grading. Mr. Markovic (W)

W256A. Advanced Engineering Electrodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 161A and 162A. Advanced treatment of concepts in electrodynamics and its applications to modern engineering problems. Vector calculus in generalized coordinate system. Solutions of wave equations in free space and materials. Reflection, transmission, and polarization. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, and sphere, including rad cross-section characterization. Green’s functions in electromagnetics and dyadic calculus. Letter grading. Mr. Ramamurthy (F)


261. Microwave and Millimeter Wave Circuits. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 163A. Rectangular and circular waveguide, microstrip, stripline, finline, and dielectric waveguide distributed circuits, with applications in microwave and millimeter wave integrated circuits. Substrate materials, surface wave phenomena. Analytical methods for discontinuity effects. Design of passive microwave and millimeter wave circuits. Letter grading. Mr. Itoh (W)


266. Computational Methods for Electromagnetics. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 162A, 163A. Computational techniques for partial differential and integral equations: finite-difference, finite-element, method of moments. Applications include transmission lines, resonant cavities, interdigital devices, microstrip, modeling, electromagnetic scattering, and antennas. Letter grading. Mr. Itoh (Sp)

270. Applied Quantum Mechanics. (4) Lecture, four hours; outside study, eight hours. Preparation: Modern Physics (or course 123A), linear algebra, and ordinary differential equations. Courses in 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. Williams (F)


277. Optical System Design. (4) Lecture, four hours; outside study, nine hours. Requisites: courses 173D and/or 174. Top-down introduction to physical layer design in fiber optic communication systems, including telecom, Datacom, and broadcast systems. Fundamentals of digital and analog optical communication systems, fiber transmission characteristics, and optical modulation techniques, including direct and external modulation and components. Advanced-level design of fiber optic transceiver circuits, including preamplifier, quantizer, clock and data recovery, laser driver, and predistortion circuits. Letter grading. Mr. Dzhanizade (F)

279A. Special Topics in Physical and Wave Electronics. (4) Lecture, four hours; outside study, eight hours. Special topics in one or more aspects of physical and wave electronics, such as electromagnetic, microwave and millimeter wave circuits, photonic and optoelectronics, plasma electronics, microelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. (Not offered 2013-14)

279CS. Clean Green IGERT Brown-Bag Seminar. (1) Seminar, one hour. Required of students in Clean Energy for Green Industry (IGERT) Research, Literature seminar presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. Mr. Huftaker (FW,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 wave propagation, ion-plasma oscillations, ion acoustic waves, cyclotron waves, hydro-magnetic waves, drift waves. Rayleigh/Taylor/Kelvin/ Helmholtz, universal, and streaming instabilities. Applications of experiments in full scale and in laboratory plasmas. Letter grading. (Not offered 2013-14)

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. (Not offered 2013-14)


285C. Academic Technical Writing for Electrical Engineers. (3) Seminar, three hours. Designed for electrical engineering Ph.D. students who have completed preliminary examinations. Students read models
598. Research for and Preparation of M.S. Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate electrical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

Scope and Objectives
At the heart of materials science is an understanding of the microstructure of solids. “Microstructure” is used broadly in reference to solids viewed at the subatomic (electronic) and atomic levels, and the nature of the defects at these levels. The microstructure of solids at various levels profoundly influences the mechanical, 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.

Department Mission
The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

Undergraduate Program Objectives
The materials engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The materials engineering program at UCLA prepares undergraduate students for employment or advanced studies with industry, the national laboratories, state and federal agencies, and academia. To meet the needs of these constituencies, the objectives of the undergraduate program are to produce graduates who (1) possess a solid foundation in materials science and engineering, with emphasis on the fundamental scientific and engineering principles that govern the microstructure, properties, processing, and performance of all classes of engineering materials, (2) understand materials processes and the application of general natural science and engineering principles to the analysis and design of materials systems of current and/or future importance to society, (3) have strong skills in independent learning, analysis, and problem solving, with special emphasis on design of engineering materials and processes, communication, and an ability to work in teams, and (4) understand and are aware of the broad issues relevant to materials, including professional and ethical responsibilities, impact of materials engineering on society and environment, contemporary issues, and need for lifelong learning.

Undergraduate Study
The Materials Engineering major is a designated capstone major. Students undertake two individual projects involving materials selection, treatment, and serviceability. Successful completion requires working knowledge of physical properties of materials, and strategies and methodologies of using materials properties in the materials selection process. Students learn and work independently and practice leadership and teamwork in and across disciplines. They are also expected to communicate effectively in oral, graphic, and written forms.

Materials Engineering B.S.
Capstone Major
The materials engineering program is designed for students who wish to pursue a professional career in the materials field and desire a broad understanding of the relationship between microstructure and properties of materials. Metals, ceramics, and polymers, as well as the design, fabrication, and testing of metallic and other materials such as oxides, glasses, and fiber-reinforced composites, are included in the course contents.

Materials Engineering Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C.

The Major
Required: Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Civil and Environmental Engineering 101 (or Mechanical and Aerospace Engineering 101), 108, Electrical Engineering 100, Materials Science and Engineering 104, 110, 110L, 120, 130, 131L, 132, 143A, 150, 160, Mechanical and Aerospace Engineering 181A or 182A; two laboratory courses (4 units) from Materials Science and Engineering 121L, 141L, 143L, 161L; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and three major field elective courses (12 units) from Chemical Engineering C114, Civil and Environmental Engineering 130, 135A, Electrical Engineering 2, 123A, 123B, Materials Science and Engineering C111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C, plus at least one elective course (4 units) from Chemistry and Biochemistry 30A, 30AL, Electrical Engineering 131A, Materials Science and Engineering 170, 171, Mathematics 170A, or Statistics 100A.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/geo/.

Electronic Materials Option
Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31 (or another programming course approved by the Faculty Executive Committee); Electrical Engineering 10; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C.

The Major
Required: Chemical Engineering 102A (or Mechanical and Aerospace Engineering 105A), Electrical Engineering 101A, 121B, Materials Science and Engineering 104, 110, 110L, 120 (or Electrical Engineering 2), 121, 121L, 122, 130, 131, 131L, Mechanical and
Aerospace Engineering 101, and 181A or 182A; four courses (16 units) from Electrical Engineering 123A, 123B, Materials Science and Engineering 132, 150, 160; 4 laboratory units from Electrical Engineering 170L, Materials Science and Engineering 141L, 161L, 199; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and one major field elective course (4 units) from Electrical Engineering 110, 131A, Materials Science and Engineering C111, 143A, 162.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22. The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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

Materials Science and Engineering M.S.

Areas of Study

There are three main areas in the M.S. program: ceramics and ceramic processing, electronic and optical materials, and structural materials. Students may specialize in any one of the three areas, although most students are more interested in a broader education and select a variety of courses. Basically, students select courses that serve their interests best in regard to thesis research and job prospects.

Course Requirements

Thesis Plan. Nine courses are required, of which six must be graduate courses. The courses are to be selected from the following lists, although suitable substitutions can be made from other engineering disciplines or from chemistry and physics with the approval of the departmental graduate adviser. Two of the six graduate courses may be Materials Science and Engineering 598 (thesis research).

Comprehensive Examination Plan. Nine courses are required, six of which must be graduate courses, selected from the following lists with the same provisions listed under the thesis plan. The remaining three courses in the total course requirement may be upper division courses.

Ceramics and ceramic processing: Materials Science and Engineering C111, 121, 122, 143A, 151, 161, 162, 200, 201, C211, 246D, 298.

Electronic and optical materials: Materials Science and Engineering C111, 121, 122, 143A, 151, 161, 162, 200, 201, C211, 222, C223, 298.


As long as a majority of the courses taken are offered by the department, substitutions may be made with the consent of the departmental graduate adviser.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101A, 102, 103, 110L, M116L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

Thesis Plan

In addition to fulfilling the course requirements, under the thesis plan students are required to write a thesis on a research topic in materials science and engineering supervised by the thesis adviser. An M.S. thesis committee composed of three departmental faculty members, including the thesis chair, reviews and approves the thesis.

Comprehensive Examination Plan

Consult the graduate adviser for details. If the comprehensive examination is failed, students may be reexamined once with the consent of the graduate adviser.

Materials Science and Engineering Ph.D.

Major Fields or Subdisciplines

Ceramics and ceramic processing, electronic and optical materials, and structural materials.

Course Requirements

There is no formal course requirement for the Ph.D. degree, and students may substitute coursework by examinations. Normally, however, students take courses to acquire the knowledge needed to satisfy the written preliminary examination requirement. In this case, a grade-point average of at least 3.33 in all courses is required, with a grade of B– or better in each course.

The basic program of study for the Ph.D. degree is built around one major field and one minor field. The major field has a scope corresponding to a body of 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. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor field is selected to support the major field and is usually a subset of the major field. For information on completing the Engineer degree, see Schoolwide Programs, Courses, and Faculty.

Written and Oral Qualifying Examinations

During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination that encompasses the body of knowledge in materials science equivalent to that expected of a bachelor’s degree. If students opt not to take courses, a written preliminary examination in the major field is required. Students may not take an examination more than twice.

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

Note: Doctoral Committees. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. Faculty members holding joint appointments with the department are considered inside members.

Fields of Study

Ceramics and Ceramic Processing

The ceramics and ceramic processing field is designed for students interested in ceramics and glasses, including electronic materials. As in the case of metallurgy, primary and secondary fabrication processes such as vapor deposition, sintering, melt forming, or extrusion strongly influence the microstructure and properties of ceramic components used in structural, electronic, or biological applications. Formal course and research programs emphasize the coupling of processing treatments, microstructure, and properties.

Electronic and Optical Materials

The electronic and optical materials field provides an area of study in the science and technology of electronic materials that includes semiconductors, optical ceramics, and thin films (metal, dielectric, and multilayer) for electronic and optoelectronic applications. Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities

Facilities in the Materials Science and Engineering Department include:

- Ceramic Processing Laboratory
- Electron Microscopy Laboratories with a scanning transmission electron microscope (100 keV), a field emission transmission electron microscope (200 keV), and a scanning electron microscope, all equipped with a full quantitative analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes
- Glass and Ceramics Research Laboratories
- Mechanical Testing Laboratory
- Metallographic Sample Preparation Laboratory
- Nano-Materials Laboratory
- Nondestructive Testing Laboratory
- Organic Electronic Materials Processing Laboratory
- Semiconductor and Optical Characterization Laboratory
- Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonding
- X-Ray Diffraction Laboratory
- X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors

Russel E. Caffisich, Ph.D. (New York U., 1978) Theory and numerical simulation for materials physics, epitaxial growth, nanoscale systems, semiconductor device properties and design in applications to quantum well devices, quantum dots, nanocrystals and quantum computing

Gregory P. Carman, Ph.D. (Virginia Tech, 1991) Electromagnetoelasticity models and characterization, thin film shape memory, nanoscale multifunctional materials, magnetoelectrics and piezoelastic materials

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

Yong Chen, Ph.D. (UC Berkeley, 1996) Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems

Bruce S. Dunn, Ph.D. (UCLA, 1974) Synthesis and characterization of electromechanical materials, energy storage, sol-gel materials and chemical vapor deposition, 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

Robert F. Hicks, Ph.D. (UC Berkeley, 1984) Chemical vapor deposition and atmospheric plasma processing


Dwight C. Streit, Ph.D. (UCLA, 1986) Properties of electronic materials, characterization techniques, correlation of material and device performance

Sarah H. Tolbert, Ph.D. (UC Berkeley, 1995) Self-organized nanostructured materials for energy storage, energy harvesting, nanomagnetics and nanoelectronics
92 / Materials Science and Engineering

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

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoscale physics, materials and devices nanoelectronics, magnetics and photonics, nonlinear interactions of correlated devices and nanosystems

Paul S. Weiss, Ph.D. (UC Berkeley, 1986)
Atomic-scale surface chemistry and physics, molecular devices, nanolithography, biophysics and neuroscience, nanometer-scale electronics and storage, surface interactions, surface motion, dynamics, and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes

Processing, characterization, and controlled delivery of biological molecules of biodegradable polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Ya-Hong Xie, Ph.D. (UCLA, 1986)
Physical properties and device application of graphene and other van der Waals materials; semiconductor physics, heterostructures, and devices; epitaxy of semiconductor thin films; nanofabrication

Jenn-Ming Yang, Ph.D. (Delaware, 1986)
Nanomechanical testing, nanostructured materials, ceramic and ceramic matrix composites, hybrid materials and composites, material synthesis and processing

Yang Yang, Ph.D. (Massachusetts-Lowell, 1992)
Organic and inorganic semiconductor materials and devices with emphasis on solution processes; fundamental understanding of material properties; optoelectronic devices (LEDs, P/NTFT, sensors)

Professors Emeriti

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

David L. Douglass, Ph.D. (Ohio State, 1958)
Oxidation and sulfidation kinetics and mechanisms, materials compatibility, defect structures, diffusion

William Klemm Jr., Ph.D. (Caltech, 1962)
Phase transformations in solids, high-pressure effects on solids

John D. Mackenzie, Ph.D. (Imperial C., London, 1964)
Glass science, ceramics, electrical properties of amorphous materials, materials recycling

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

Alv H. Shabakhty, Ph.D. (UC Berkeley, 1966)
Metal forming, metal cutting, mechanical properties, friction and wear, biomaterials, manufacturing processes

George H. Sine, Ph.D. (UCLA, 1953)
Fracture of ceramics, fatigue of metals, carbon-carbon composites, failure analysis

Alfred S. Yue, Ph.D. (Purdue, 1967)
Semiconductor electronics, electronic materials for solar cell and detector applications, solidification and crystal growth

Associate Professors

Yu Huang, Ph.D. (Harvard, 2003)
Nanomaterial fabrication and development, bio-nano structures

Iooana Kakoulli, D.Phil. (U.Oxford, United Kingdom, 1999)
Chemical and physical properties of non-metallic archaeological materials; alteration processes in archaeological vitreous materials and pigments

Suneel Kodambaka, Ph.D. (Illinois, Urbana-Champaign, 2002)
In situ microscopy, surface thermodynamics, kinetics of crystal growth, phase transformations and chemical reactions, thin film physics

Adjunct Professor

Harry Patton Gillis, Ph.D. (Chicago, 1974)
Application of surface science and chemical dynamics and techniques to elucidate fundamental molecular mechanisms and optimize practical processes

Adjunct Associate Professors

Eric P. Bescher, Ph.D. (UCLA, 1987)
Advanced cementitious materials, sol-gel materials, organic/inorganic hybrids

Kosmas Galalis, Ph.D. (RMIT U., Australia, 2002)
Dilute magnetic semiconductors for Spintronics applications, nano-technology, understanding of alternative state variables for electronic devices

Lower Division Courses

10. Freshman Seminar: New Materials. (1)
Seminar, one hour; outside study, two hours. Preparation: high school chemistry and physics. Not open to students with credit for course 104. 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.

19. Fiat Lux Freshman Seminars. (1)
Lecture, 30 minutes; discussion, 30 minutes. Preparation: one hour. Students must obtain permission from the instructor to register after the first week of classes. Whimsical topics presented by faculty members in their areas of expertise and illuminating members in their areas of expertise and illuminating their fundamental differences and their applications in advanced technology. Microstructural analysis and various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. Letter grading.

20L. Introduction to Materials Characterization A (Crystalline Materials), (2) (Formerly numbered 20J.) Lecture, four hours; discussion, two hours; outside study, two hours. Preparation: Chemistry 20A, 20B. General introduction to different methods of materials characterization; fundamentals of characterization, properties of X rays, X-ray scattering, powder method, Laue method; determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray spectroscopy; design of materials characterization procedures. Letter grading.

C111. Introduction to Materials Characterization B (Electron Microscopy). (4) (Formerly numbered 111.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Preparation: courses 104, 110. Characterization of microstructure and microscopic chemical analysis 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. Concurrently scheduled with course C211. Letter grading.


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: requisites: courses 104, 110 (or Chemistry 113A), Introduction to electrical, optical, and magnetic properties of solids. Free electron model, introduction to band theory and Schrödinger wave equation, Crystal bonding and lattice vibrations. Mechanisms and characterization of electrical conductivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading.

121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: courses 104, 208. Structure and properties of elemental and composite semiconductors. Electrical and optical properties, defect chemistry, and doping. Electronic materials analysis and characterization, including electrical, optical, and ion-beam techniques. Hot-electron techniques, two-gap engineering, development of new materials for optoelectronic applications. Letter grading.

M. Huang (Sp)

122L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Corequisites: course 121. Experiments conducted on materials characterization, including measurement of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

M. Goorsky (Sp)
122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisites: course 104, and Chemical Engineering 105A. Study 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. Soroka (W)

130. Phase Relations in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 104, and Chemical Engineering 105A. Thermodynamic laws, equilibrium criteria, solution thermodynamics, mass action law, binary and ternary phase diagrams, glass transitions. Letter grading. Mr. Tu (F)

131L. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, diffusion 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. Wu (W)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Corequisite: course 131. Design of heat-treatment experiments; 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)


CM133. Ancient and Historic Metals: Technology, Microstructure, Corrosion, and Conservation. (4) Lecture, two hours; laboratory, 90 minutes. Processes of extraction, alloying, surface patination, metallic coatings, corrosion, and microstructure of ancient and historic metals. Extensive laboratory work in preparation and examination of metallic samples under microscopy, as well as lectures on technology of metallic works of art. Practical instruction in metallographic microscopy and electron microscopy; interpretation of crystallographic data; selection and application of methods for identification of metallic materials. Letter grading. Mr. Dunn (Sp)

140. Materials Selection and Engineering Design. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: at least two courses from 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymers, ceramic, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading. Mr. J.-M. Yang (Sp)

141L. Computer Methods and Instrumentation in Materials Science and Engineering Laboratory. (2) 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, data acquisition and processing, computer-aided testing. Letter grading. Mr. Goosky (W)

143. Mechanical Behavior of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 104, Mechanical and Aerospace Engineering 101. Plastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocations, fracture, microstructural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. J.-M. Yang (W)

143L. Mechanical Behavior Laboratory. (2) Laboratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Designed to characterize mechanical behavior of various materials; elastic and plastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. Ono

150. Introduction to Polymers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, structure, crystallinity, and morphology and their effects on physical properties. Glassy polymers, springy polymers, elastomers, adhesives. Fiber forming polymers, polymer processing technology, plasticization. Letter grading. Mr. Pei (W)


160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 130. Introduction to ceramics and glasses being used as important engineering materials; processing techniques, unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading. Mr. Dunn (F)

161. Processing of Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 160. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, greenware forming, sintering, glass melting. Microstructure properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading. Mr. Dunn

161L. Laboratory in Ceramics. (2) Laboratory, four hours; outside study, eight hours. Enforced requisite: course 161. Attainment of specific properties through process control for engineering applications. Quantitative characterization and selection of raw materials. Slip casting and extrusion of clay bodies. Sintering of powders. Glass melting and fabrication. Determination of chemical and physical properties. Letter grading. Mr. Dunn (Sp)

162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Electrical Engineering 1 or Physics 1C). Utilization of ceramics in modern electronic devices, thin film and multilayer capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferroelectrics and electrooptic devices; optical wave guide applications and designs. Letter grading. Mr. Dunn

170. Engaging Elements of Communication: Oral Communication. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive oral presentation and communication skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentations, as well as public speaking engagements. Learning environment is highly supportive and interactive as it helps students creatively develop and present their own ideas and arguments. Letter grading. Mr. Xie

171. Engaging Elements of Communication: Writing for Technical Community. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive technical writing skills on subjects specific to field of materials science and engineering from given set of journal publications. Instruction leads students through the writing process, including brainstorming, choosing title, coming up with outline, concise writing of abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and professional tone. Letter grading. Mr. Xie

CM180. Introduction to Biomaterials. (4) Same as Bioengineering CM178.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing, and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading. Mr. Wu (W)

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 taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students concurrently scheduled with course CM233. Letter grading. May be repeated once for credit with approval of research methods and current literature in field of research of faculty members or students. May be repeated twice for credit. Letter grading.

199. Directed Research in Materials Science and Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/senior. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. Occasional field trips may be arranged. May be repeated for credit with approval of individual contract. Enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F, W, Sp)

Graduate Courses

200. Principles of Materials Science I. (4) Lecture, four hours; outside study, four hours; eight hours. Requisite: course 120. Lattice dynamics and thermal properties of solids, classical and quantized free electron theory, electrons in a periodic potential, transport in semiconductors, dielectric and magnetic properties of solids. Letter grading. Mr. Y. Yang (F)


210. Diffraction Methods in Science of Materials. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Requisite: course 110. Theory of diffraction of waves (X rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of plastic deformation, solid-state transformations, arrangements of atoms in liquids and amorphous solids. Letter grading. Mr. Goosky (Sp, odd years)

C211. Introduction to Materials Characterization B (Electron Microscopy) (4) F, W, Sp, Summer (Same as Conservation 211.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereo graphic projection, direct observation of defects in crystals, replicas; scanning electron microscopy: electron microscopy and analysis; electron optics of both instruments. Concurrently scheduled with course C111. Letter grading. Mr. Kodambaka (Sp, even years)


251. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft chemical materials: organic polymers, biomolecules, and biomaterials. Extensive description and discussion of structure-property relationship, spectroscopic and experimental techniques, and preparation methods for various soft materials. Letter grading. Mr. Pei (F)

270. Computer Simulations of Materials. (4) Lecture, four hours; outside study, eight hours. Introduction to modern methods of computational modeling in materials science. Topics include basic statistical mechanics, classical molecular dynamics, and Monte Carlo methods, with emphasis on understanding basic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of examples from current literature to illustrate these methods. Letter grading. Mr. Ozolins (W)

274. Electronic Properties of Ceramics and Glasses. (4) Lecture, two hours; outside study, eight hours. Principles of electronic properties of ceramic and glass materials. Topics include structure, bonding, and charge transport in ceramics and glasses. Letter grading. Mr. M. Zhang (Sp)

275. Electronic and Optical Properties of Materials. (4) Lecture, two hours; outside study, eight hours. Principles of electronic and optical properties of materials. Topics include electronic and optical properties of metals, semiconductors, and insulators. Letter grading. Mr. M. Zhang (Sp)

284. Advanced Materials Science of Surfaces. (4) Lecture, four hours; outside study, eight hours. Preparation: Basic knowledge of surface science and engineering. Requisite: course 151. Applications of surface science in material processing, chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition processes. Letter grading. Mr. Xie

291. Materials Science of Solar Cells. (4) Lecture, four hours; outside study, eight hours. Preparation: Basic knowledge of semiconductor science and technology. Requisite: course 151. Physics of solar cells, such as organic solar cell, thin-film solar cells, and multiple junction solar cells. Letter grading. Mr. Y. (Sp)

295. Materials Science of Bartholomew. (4) Lecture, four hours; outside study, eight hours. Preparation: Basic knowledge of semiconductor science and technology. Requisite: course 151. Future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. Bartholomew

296. Introduction to Biomaterials. (4) (Same as Bioengineering CM278.) Lecture, three hours; discussion, two hours; outside study, seven hours. Preparation: course 29A, 29B, and 21L. Engineering materials used in medicine and dentistry

296C. Introduction to Bioceramics. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Preparation: Basic knowledge of ceramic science and technology. Requisite: course 151. Fundamentals of bioceramics, including bones, teeth, and dental materials. Letter grading. Mr. Bartholomew

296D. Introduction to Biopolymers. (4) Lecture, four hours; discussion, two hours. Preparation: Basic knowledge of polymer science and technology. Requisite: course 151. Fundamentals of biopolymers, including natural and synthetic polymers used in medicine and dentistry.
Mechanical and Aerospace Engineering

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H. Thomas Hahn, Ph.D. (Raytheon Company Professor Emeritus of Manufacturing Engineering)
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Pei-Yu Chiou, Ph.D.
Jeff D. Eldredge, Ph.D.
H. Pirouz Kavehpour, Ph.D.
William S. Klug, Ph.D.

Scope and Objectives
The Department of Mechanical and Aerospace Engineering offers curricula in aerospace engineering and mechanical engineering at both the undergraduate and graduate levels. The scope of the departmental research and teaching program is broad, encompassing dynamics, fluid mechanics, heat and mass transfer, manufacturing and design, nanoelectromechanical and micro-electromechanical systems, structural and solid mechanics, and systems and control. The applications of mechanical and aerospace engineering are quite diverse, including aircraft, spacecraft, automobiles, energy and propulsion systems, robotics, machinery, manufacturing and materials processing, microelectronics, biological systems, and more.

At the undergraduate level, the department offers accredited programs leading to B.S. degrees in Aerospace Engineering and in Mechanical 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
The aerospace engineering and mechanical engineering programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

In consultation with its constituents, the Mechanical and Aerospace Engineering Department has set its educational objectives as follows: within a few years after graduation, the students will be successful in careers in aerospace or mechanical or other engineering fields, and/or in graduate studies in aerospace or mechanical or other engineering fields, and/or in further studies in other fields such as medicine, business, and law.

Undergraduate Study
The Aerospace Engineering and Mechanical Engineering majors are designated capstone majors. Within their capstone courses, Aerospace Engineering students are exposed to the conceptual and design phases for aircraft development and produce a structural design of a component, such as a light-weight aircraft wing. Mechanical Engineering students work in teams in their capstone courses to propose, design, analyze, and build a mechanical or electromechanical device. Graduates of both programs should be able to apply their knowledge of mathematics, science, and engineering in technical systems; design a system, component, or process to meet desired needs; function as productive members of a team; identify, formulate, and solve engineering problems; and communicate effectively, both orally and in writing.

Aerospace Engineering B.S.
Capstone Major
The 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 aerelasticity, dynamics, control and guidance, propulsion, and energy conversion.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 94; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, C150P, 150R or 161A, 154S, 157A, 157S, 166A, 171A, 182A; two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104)—if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper division course or courses from the department—except for Mechanical and Aerospace Engineering 156A—or, by petition, from outside the department; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Mechanical and Aerospace Engineering 154A, 154B); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 105D, 131A, 131AL, 132A, 133A, 133AL, 134, 135, 136, CM140, 150C, 155, 157A, 161A, 161B, 163A, 166C, M168, 169A, 171B, 172, 174, C175A, CM180, 181A, 182B, 182C, 183, 184, 185, C186, C187L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Mechanical Engineering B.S.
Capstone Major
The mechanical engineering program is designed to provide basic knowledge in thermodynamics, fluid mechanics, heat transfer, solid mechanics, mechanical design, dynamics, control, mechanical systems, manufacturing, and materials. The program includes fundamental subjects important to all mechanical engineers.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Computer Science 31; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 94; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Electrical Engineering 110L, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 131A or 133A, 156A, 157, 162A, 171A, 182A, 183; two departmental breadth courses (Electrical Engineering 100 and Materials Science and Engineering 104)—if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper division course or courses from the department—except for Mechanical and Aerospace Engineering 166A—or, by petition, from outside the department; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Mechanical and Aerospace Engineering 162D, 162E); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131A (unless taken as a required course), 131AL, C132A, 133A (unless taken as a required course), 133AL, 134, 135, 136, CM140, 150A, 150B, 150C, C150P, 150R, 153A, 154S, 155, 157A, 161A, 161B, 163A, 166C, M168, 169A, 171B, 172, 174, C175A, CM180, 181A, 182B, 182C, 183, 184, 185, C186, C187L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 18 or http://www.registrar.ucla.edu/ge/.

Graduate Study
For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.

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. All new M.S. and Ph.D. students who are pursuing an M.S. degree in the Mechanical and Aerospace Engineering Department must meet with their advisers in their first term at UCLA. The goal of the meeting is to discuss the students’ plans for satisfying the
M.S. degree requirements. Students should obtain an M.S. planning form from the department Student Affairs Office and return it with their advisers’ signature by the end of the first term.

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 (and 36 units) 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. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. The courses should be selected so that the breadth requirements and the requirements at the graduate level are met. The breadth requirements are only applicable to students who do not have a B.S. degree from an ABET-accredited aerospace or mechanical engineering program.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101A, 102, 103, 110L, M161L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 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 C150P, (3) 131A or 133A, (4) 156A, (5) 162D 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, 250B, 255A, M256A, M256B, M269A, C271A, 294, or 297. The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D 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, 250B, 255A, M256A, M256B, M269A, C271A, 294, or 297. 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, or (3) take and pass three comprehensive examination questions offered in association with three mechanical and aerospace engineering graduate courses. Contact the department Student Affairs Office for more information.

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 (and 36 units) 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. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. Choices may be made from the following major areas:

Undergraduate Courses. No lower division courses may be applied toward graduate...
degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199; Civil and Environmental Engineering 106A, 108, 199; Computer Science M152A, 152B, M171L, 199; Electrical Engineering 100, 101A, 102, 103, 110L, M161L, M171L, 199; Materials Science and Engineering 110, 120, 130, 131L, 132, 140, 141L, 150, 160, 161L, 199; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 163A, M168, 174, 183, 184, 185.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, CM280A, 293, 294, 295B, 296A, 296B, 297.


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, or (3) take and pass three comprehensive examination questions offered in association with three graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students would normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Aerospace Engineering Ph.D. and Mechanical Engineering Ph.D.

Major Fields or Subdisciplines

Dynamics; fluid mechanics; heat and mass transfer; manufacturing and design (mechanical engineering only); nanoelectromechanical/microelectromechanical systems (NEMS/MEMS); structural and solid mechanics; systems and control.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature or (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 members 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 term following the term in which the examination is given. The examination must be taken within the first two calendar years from the time of admission into the Ph.D. program. Students must be registered during the term 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 into 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 in the department. The outside member must be a UCLA faculty member in another 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; experimental studies of electromechanical systems; and robotics.

Fluid Mechanics
The graduate program in fluid mechanics includes experimental, numerical, and theoretical studies related to a range of topics in fluid mechanics, such as turbulent flows, hypersonic flows, microscale and nanoscale flow phenomena, aeroacoustics, biofluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, biofluid mechanics, hypersonics, reactive flow, fluid stability, turbulence, and experimental methods.

Heat and Mass Transfer
The heat and mass transfer field includes studies of convection, radiation, conduction, evaporation, condensation, boiling and two-phase flow, chemically reacting and radiating flow, instability and turbulent flow, reactive flows in porous media, as well as transport phenomena in support of micro-scale and nanoscale thermosciences, energy, bioMEMS/NEMS, and microfabrication/nanofabrication.

Manufacturing and Design
The program is developed around an integrated approach to manufacturing and design. It includes study of manufacturing and design aspects of mechanical systems, material behavior and processing, robotics and manufacturing systems, CAD/CAM theory and applications, computational geometry and geometrical modeling, composite materials and structures, automation and digital control systems, microdevices and nanodevices, radio frequency identification (RFID), and wireless systems.

Nanoelectromechanical/Microelectromechanical Systems
The nanoelectromechanical/microelectromechanical systems (NEMS/MEMS) field focuses on science and engineering issues ranging in size from nanometers to millimeters and includes both experimental and theoretical studies covering fundamentals to applications. The study topics include microscience, top-down and bottom-up nanofabrication/microfabrication 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 program 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, analysis of coupled electromagneto-thermomechanical material systems, and ferroelectric materials. The structural mechanics program includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aerelasticity, fluid structure interaction, computational transonic aerelasticity, bio-mechanics with applications ranging from whole organs to molecular and cellular structures, structural optimization, finite element methods and related computational techniques, structural mechanics of composite material components, structural health monitoring, and analysis of adaptive structures.

Systems and Control
The program features systems engineering principles and applied mathematical methods of modeling, analysis, and design of continuous- and discrete-time control systems. Emphasis is on modern applications in engineering, systems concepts, feedback and control principles, stability concepts, applied optimal control, differential games, computational methods, simulation, and computer process control. Systems and control research and education in the department cover a broad spectrum of topics primarily based in aerospace and mechanical engineering applications. However, the Chemical and Biomolecular Engineering and Electrical Engineering Departments also have active programs in control systems, and collaboration across departments among faculty members and students in both teaching and research is common.

Ad Hoc Major Fields
The ad hoc major fields program has sufficient flexibility that students can form academic major fields in their area of interest if the proposals are supported by several faculty members. Previous fields of study included acoustics, system risk and reliability, and engineering thermodynamics. Nuclear science and engineering, a former active major field, is available on an ad hoc basis only.

Facilities
The Mechanical and Aerospace Engineering Department has a number of experimental facilities at which both fundamental and applied research is being conducted. More information is at http://www.mae.ucla.edu.

Active Materials Laboratory
The Active Materials Laboratory contains equipment to evaluate the coupled response of materials such as piezoelectric, 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.

Autonomous Vehicle Systems Instrumentation Laboratory
The Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL) is a testbed at UCLA for design, building, evaluation, and testing of hardware instrumentation and coordination algorithms for multiple vehicle autonomous systems. The AVSIL contains a hardware-in-the-loop (HIL) simulator designed and built at UCLA that allows for real-time, systems-level tests of two formation control computer systems in a laboratory environment, using the 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.

Computational Fluid Dynamics Laboratory
The Computational Fluid Dynamics Laboratory has several medium-size Beowulf Linux clusters for numerical simulation of transitional, turbulent, and high speed compressible flows, with and without reaction, as well as the sound that they produce. The laboratory has access to supercomputers (large clusters of parallel processors on various platforms) at NSF PACI Centers and DoD High-Performance Computing Centers.
Energy and Propulsion Research Laboratory

The Energy and Propulsion Research Laboratory is engaged in research and education pertaining to the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research is directed toward the development of fundamental engineering knowledge as well as tools for solving critical national problems, with current applications to improved engine efficiency, reduced emissions, alternative fuels, and advanced high-speed air breathing and rocket propulsion systems.

Fluid Mechanics Research Laboratory

The Fluid Mechanics Research Laboratory includes a full line of water tunnels equipped with various advanced transducers (MEMS-based sensors and actuators, particle image anemometer, laser Doppler anemometer, hot-wire anemometers) and data acquisition systems.

Fusion Science and Technology Center

The Fusion Science and 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 dynamics and heat transfer, (2) thick and thin liquid metal systems exposed to intense particle and heat flux loads, and (3) metallic and ceramic material thermo-mechanics.

Heat Transfer Laboratories

The Heat Transfer Laboratories are used for experimental research on heat transfer and thermal hydraulics. The laboratories are equipped with several flow loops, high-current power supplies, high-frequency induction power supplies, holography and hot-wire anemometry setups, and state-of-the-art data acquisition systems.

Materials Degradation Characterization Laboratory

The Materials Degradation Characterization Laboratory is used for the characterization of the degradation of high-strength metallic alloys and advanced composites due to corrosion and fatigue, determination of adverse effects of materials degradation on the strength of structural components, and for research on fracture mechanics and ultrasonic nondestructive evaluation.

Micro and Nano Manufacturing Laboratory

The Micro and Nano Manufacturing Laboratory is equipped with a fume hood, wafer saw, wire bonder, waterjet cutting machine, a waterjet cutting machine, a stereo lithography machine, a laminated object manufacturing machine, a coordinate measuring machine, a field emission scanning electron microscope, an atomic force microscope, an AFM, a rhenometer, a thermal analysis system, an RCL analyzer, a microdielectric analyzer, an X-ray radiography machine, and a variety of mechanical testing machines.

Multiscale Thermosciences Laboratory

The Multiscale Thermosciences Laboratory (MTSL) is equipped with a state-of-the-art atomic force microscope, an inverted optical microscope with fluorescence attachment, an ultra-long depth-of-field digital microscope, an infrared camera, a cryostat, an RF frequency lock-in amplifier, semiconductor lasers, a wide variety of electronic instruments/DAQ systems, and a quad-core workstation with 32GB RAM.

Plasma and Beam Assisted Manufacturing Laboratory

The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for the purpose of processing and manufacturing advanced materials by high-energy means (plasma and beam sources). It is equipped with plasma diagnostics, two vortex gas tunnel plasma guns, powder feeder and exhaust systems, vacuum and cooling equipment, high-power D.C. supplies (400kW), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

Plasma Propulsion Laboratory

The Plasma Propulsion Laboratory includes vacuum systems, power supplies, and diagnostics for the study of plasma propulsion devices.

Subsonic Wind Tunnel

The 3x3-foot Subsonic Wind Tunnel is used for research on unsteady aerodynamics on oscillating airfoils and instruction.

Thin Films, Interfaces, Composites, Characterization Laboratory

The Thin Films, Interfaces, Composites, Characterization Laboratory consists of a Nd:YAG laser of 1 Joule capacity with three ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 Kip-capacity servohydraulic biaxial test frame, walk-in freezer, polishing and imaging equipment for microstructural characterization for measurement and control study of thin film interface strength, NDE using laser ultrasound, de-icing of structural surfaces, and characterization of composites under multi-axial stress state.

Faculty Areas of Thesis Guidance

Professors

Mohamed A. Abdou, Ph.D. (Wisconsin, 1973) Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermal-mechanics; thermal hydraulics; fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-material interactions; blankets and high heat flux components; experiments; modeling and analysis

Oddvar O. Bendiksen, Ph.D. (UCLA, 1980) Classical and computational aeroelasticity, structural dynamics and unsteady aerodynamics
Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
 Electromagnetoelasticity models, fatigue characterization of piezoelectric ceramics, magnetostrictive components, characterization of shape memory alloys, fiber-optic sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally measured properties

Ivan Catton, Ph.D. (UCLA, 1966)
 Heat transfer and fluid mechanics, transport phenomena in porous media, nucleic acid heat transfer and thermal hydraulic, natural and forced convection, thermal/hydrodynamic stability, turbulence

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

Yong Chen, Ph.D. (UC Berkeley, 1996)
 Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, micro- and nanoscale electronic, mechanical, optical, biological, and sensor devices, circuits, circuits and systems

Vijay K. Dhir, Ph.D. (U. Kentucky, 1972)
 Thermohydraulic heat transfer, boiling and condensation, thermal hydraulic of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling

Rajit Gadh, Ph.D. (Cornell, 1991)
 Mobile Internet, web-based product design, high-power density electronic cooling

Ann R. Karagozian, Ph.D. (Caltech, 1982)
 Fluid mechanics and combustion with applications to cloud and aerosols in the earth’s atmosphere

Chang-Jin (C-J) Kim, Ph.D. (UC Berkeley, 1991)
 Microelectromechanical systems; micro/nano fabrication technologies, structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)

John Kim, Ph.D. (Stanford, 1978)
 Turbulence, numerical simulation of turbulent and transitional flows, application of control theories to flow control

Adrienne Lavine, Ph.D. (UC Berkeley, 1984)
 Heat transfer: thermomechanical behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection

 Radiative transfer and satellite remote sensing with applications to cloud and aerosols in the earth’s atmosphere

Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1992)
 Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensor and actuator applications, fracture mechanics and failure analysis

Alla Atluri, Ph.D. (Calcutta Univ., 2004)
 Mechanics of solids, fractures and failure, wave propagation, nondestructive evaluation, composite materials

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

Laurent G. Pilon, Ph.D. (Purdue, 2002)
 Interfacial and transport phenomena, radiation transfer, materials synthesis, multi-phase flow, heterogenerous materials

Jason L. Speyer, Ph.D. (Harvard, 1968)
 Stochastic and deterministic optimal control estimation with application to aerospace systems; guidance, flight control, and flight mechanics

Tsu-Chin Tsao, Ph.D. (UC Berkeley, 1988)
 Modeling and control of dynamic systems with applications in mechatronic systems, manufacture processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

James S. Gibson, Ph.D. (U. Texas, Austin, 1975)
 Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Professor Emeriti

 Aerelasticity of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of sound radiation, structural optimization with aeroelastic constraints

H. Thomas Hahn, Ph.D. (Pennsylvania State, 1977)
 Nanocomposites, multifunctional composites, nanomechanics, rapid prototyping, information systems

 Thermal convection, thermocapillary convection, stability of shear flows, stratified and rotating flows, interfacial phenomena, microgravity fluid dynamics

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

Anthony F. Mills, Ph.D. (UC Berkeley, 1965)
 Convective heat and mass transfer, condensation heat transfer, turbulent flows, evaporation and transpiration cooling, perforated plate heat exchangers

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

Peter A. Monkewitz, Ph.D. (E.T.H., Federal Institute of Technology, Zurich, 1977)
 Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip F. O’Brien, M.S. (UCLA, 1949)
 Industrial engineering, environmental design, thermal and luminous engineering systems

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

Owen I. Smith, Ph.D. (UC Berkeley, 1977)
 Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition

Richard Stern, Ph.D. (UCLA, 1964)
 Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics

Russell A. Westmann, Ph.D. (UC Berkeley, 1962)
 Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems

Daniel C. Yang, Ph.D. (Rutgers, 1982)
 Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

Associate Professors

Pei-Yu Chou, Ph.D. (UC Berkeley, 2005)
 BioMEMS, biophotonics, electrooptics, optical manipulation, optoelectronic devices

Jeff D. Eldredge, Ph.D. (Caltech, 2002)
 Numerical simulation of fluid dynamics, bio-inspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vorticity-based numerical methods, simulations of biomedical flows

H. Pirouz Kavehpour, Ph.D. (MIT, 2003)
 Microscale fluid mechanics, transport phenomena in biological systems, physics of contact line phenomena, complex fluids, non-isothermal flows, micro- and nano-heat guides, microbiology

 Computational structural and solid mechanics, finite element methods, computational biomechanics, nanomechanics of biological systems

Assistant Professors

Jonathan B. Hopkins, Ph.D. (MIT, 2010)
 Design and manufacturing of microstructural architectures, flexure systems, and compliant mechanisms; screw down micromechanics, precision machine design; novel micro- and nano-fabrication processes; MEMS

Richard E. Witz, Ph.D. (Caltech, 2005)
 Space and plasma plasma, partially ionized plasma discharges, behavior of miniature plasma devices, spacecraft and space mission design, wind energy, solar thermal energy

Lecturers

Ravesh C. Amar, Ph.D. (UCLA, 1974)
 Heat transfer and thermal science

Amya K. Chatterjee, Ph.D. (UCLA, 1976)
 Elastic wave propagation and penetration dynamics

Carl F. Rued, Ph.D. (Caltech, 1993)
 Robotics, computing, mechanical design, instrument technology, technology management

Adjunct Professors

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

Wilbur J. Marner, Ph.D. (UC Davis, 1969)
 Thermal sciences, systems design

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

Robert S. Shaver, Ph.D. (UCLA, 1985)
 Radiation interaction with materials, microstructure evolution modeling, plasma and laser processing, fusion technology research, fusion
principles of mechanics to flow of compressible and incompressible fluids. Letter grading.

104A. Introduction to Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological thermodynamics. Concepts of equilibrium, temperature, and reversibility. First law and concept of energy; second law and concept of entropy. Equations of state and thermodynamic properties. Engineering applications of these principles in analysis and design of closed and open systems. Letter grading. Mr. Pilon (F,Sp)

105D. Transport Phenomena. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A, Mathematics 32B, 33B. Transport phenomena: heat conduction, mass species diffusion, convective heat and mass transfer, and radiation. Engineering applications in thermal and environmental control. Letter grading. Mr. Ju (F)

107. Introduction to Modeling and Analysis of Dynamic Systems. (4) Lecture, four hours; discussion, one hour; laboratory, two hours; outside study, five hours. Requisites: Computer Science 31, Electrical Engineering 100 (enforced). Introduction to modeling of physical systems using differential equations of mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency response, first- and second-order system transient analysis, and numerical solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response. Block diagram representation of steady state interconnection of systems. Hands-on experiments reinforce lecture material. Letter grading.


131AL. Thermodynamics and Heat Transfer Laboratory. (4) Lecture, four hours; laboratory, eight hours; outside study, six hours. Requisites: courses 131A, 157 or 157S. 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 cooling tower, heat exchanger, and internal combustion engine. Students take and analyze data and discuss physical phenomena. Letter grading. Mr. Pilon (Not offered 2013-14)


133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, reactive and nonreactive fluid flow systems. Letter grading. Mr. Catton (F,Sp)

133AL. Power Conversion Thermodynamics Laboratory. (4) Lecture, eight hours; outside study, four hours. Requisites: courses 131A, 157 or 157S. Experimental study of power conversion and heat transfer systems using state-of-art plant process instrumentation and equipment. Experiments include studies of thermodynamic operating characteristics of actual Brayton cycle engine cycle, compressive refrigeration unit, and absorption refrigeration unit. Letter grading. Mr. Catton (Sp)

134. Design and Operation of Thermal Hydraulic Power Systems. (4) Lecture, four 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, fluid systems, heat exchangers, refrigeration units, absorption refrigeration units, compressors, valves and piping systems, and instrumentation and control systems. Letter grading. Mr. Catton (Not offered 2013-14)

135. Fundamentals of Nuclear Science and Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 105D. Recommended: courses 131A, 133A. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, geothermal, solar, wind, and ocean, fuel cells, transportation, energy conservation, and water pollution, global warming. Letter grading. Mr. Abdou (F)

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 105D. Recommended: courses 131A, 133A. Global energy use and supply, electrical power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, geothermal, solar, wind, and ocean, fuel cells, transportation, energy conservation, and water pollution, global warming. Letter grading. Mr. Catton (Not offered 2013-14)

CM140. Introduction to Biomechanics. (4) (Same as Bioengineering CM140) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 101, 102, 156A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function, Dynamics. Fluid dynamics. Mechanical applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading. Mr. Eldredge, Ms. Karagozian (F,Sp)


150B. Aerodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 131A, 150A. Advanced aspects of potential flow theory. Incompressible flow around thin airfoils (lift and moment coefficients) and wings (lift, induced drag). Gas dynamics: oblique shocks, Prandtl-Meyer expansion, and super sonic flow around thin airfoils and wings. Wave drag, Transonic flow. Letter grading. Mr. Zhong (Sp)

C150G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: 105A, 110A. First course design courses. Student groups continue experimental programs and use of modern experimental tools and techniques in field. Letter grading. Mr. Ghoniem (F,W,S)

157A. Fluid Mechanics and Aerodynamics Laboratory. (L) Laboratory, four hours; outside study, four hours. Requisites: courses 150A or 150B, 157A or 157C. Experimental study of transport phenomena in fluids. Physical principles and basic laws for modeling flow in channels, pipes, and ducts. Letter grading. Mr. Ghoniem (W)

157B. Basic Aerospace Engineering Laboratory. (L) Laboratory, eight hours; outside study, four hours. Enforced requisites: courses 150R and 151R. Aerodynamics and propulsion concepts, including performance and stability, and control concepts. Designs or competition. Preparation of design project presentations in both oral and written formats. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)

163A. Introduction to Computer-Controlled Machine Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 182A. Not open to students with credit for course 156A. Introduction to two-dimensional drafting, stress analysis, fatigue; bending of beams; torsion of beams; warping; torsion of thin-walled 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. Carman (F)

166C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 150A, 150B, and 157S. Analysis and design of composite materials, laminates, fibers, and matrixes. Letter grading. Mr. Ghoniem, Mr. Tsao (W)

161A. Introduction to Aeronautics. (4) Lecture, four hours; discussion, four hours; outside study, six hours. Enforced requisites: courses 101, 102, 103, 105A, 166A. Electrical Engineering 100. Recommended: courses 150A and 157A. Performance of experiments to enhance understanding of basic physical principles and characteristics of structures, materials, and engines with relevance to aerospace engineering. Letter grading. Mr. Ju (W,S)

161B. Introduction to Space Technology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended preparation: courses 102, 150P, 161A. Introduction to space technology and applications. Letter grading. Mr. Wirz (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161B. Coverage of preliminary design, by students, of small spacecraft carrying lightweight scientific payloads. Emphasis on conceptual design, cost, lifetime, and attitude stability. Students work in groups of three or four, with each student responsible primarily for one subsystem and for integration with other students. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)

161D. Space Technology Hardware Design. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Recommended requisite or corequisite: course 161B. Design, by students, of hardware with applications to space technology. Designs are then built by HSSEAS professional machine shop and tested by students. New project carried out each year. Letter grading. Mr. Wirz (W)

162A. Introduction to Mechanisms and Mechanic- cal Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 102, 102, 103, 105A, 166A. Mechanical 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 (F,W,S)

162B. Mechanical Engineering Design I. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 162B. Limited to seniors. Second of two mechanical engineering capstone design courses. Students groups continue design projects started in course 162B, making use of CAD design laboratory, CAD analysis laboratory, and mechatronics laboratory. Design theory, design tools, economics, decision-making, ethics, intellectual property, design for manufacture and assembly, design for safety and reliability, and engineering ethics. Students conduct hands-on design, fabrication, and testing. Culminating project demonstrations or competition. Preparation of design project presentations in both oral and written formats. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)

163A. Introduction to Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 182A. Not open to students with credit for course 156A. Introduction to two-dimensional fluid mechanics, stress analysis, heat transfer, and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postprocessing techniques; term projects with computers. Letter grading. Mr. Chen, Mr. Klug (F,S)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 150A or 166A. Advanced study in the areas of lumped and distributed parameter systems. Spectral methods, stability, and bifurcation. Letter grading. Mr. Chen (W)

171A. Introduction to Feedback and Control Systems: Dynamic Systems Control I. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 107, 182A. Introduction to feedback principles, control systems design, and system stability. Modeling of physical systems in engineering and other fields. Transfer functions; controller design using Nyquist, Bode, and root
locus methods; compensation; computer-aided analysis and design. Letter grading.

Mr. M'Closey (Fall, Spring)

171B. Digital Control of Physical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 171A or Electrical Engineering 141. Analysis and design of digital control systems. Introduction to Digital Computer and Discrete-time system representation. Design using classical methods: performance specifications, root locus, frequency response, loop-shaping compensa-
tion. Design using space-state methods: state feed-
back, state estimator, state estimator feedback con-
trol. Simulation of sampled data systems and practi-
cal aspects: roundoff errors, sampling rate selection, computation delay. Letter grading.

Mr. Tsao (Not offered 2013-14)

172. Control System Design Laboratory. (4) Lecture, three hours; laboratory, two hours; outside study, seven hours. Enforced requisite: course 171A. Introduction to loop shaping controller design with application to laboratory electromechanical systems. Power spectrum models of noise and disturbances, and performance trade-offs imposed by conflicting requirements. Constraints on sensitivity function and complementary sensitivity function imposed by non-
minimum phase plants. Lecture topics supported by weekly hands-on laboratory work. Letter grading.

Mr. Ghoniem (Not offered 2013-14)

174. Probability and Its Applications to Risk, Reli-
ability, and Quality Control. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requi-
site: Mathematics 33A. Introduction to probability theory; random variables, distributions, function of random variables, models of failure of components, reliability, redundancy, complex systems, stress-
strength conditions, Gumbel/Markov sequence, and minimum variance estimator (Kalman filter) with applic-
tions. Concurrently scheduled with course C271A. Letter grading.

Mr. Speyer (Fall, Winter, Spring)

CM180. Introduction to Micromachining and Mi-
croelectromechanical Systems (MEMS). (4) Same as Bioengineering CM150 and Electrical Engineering CM150.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20C, Computer Science 4AL, 4BL. Introduction to micromachining technologies and microelectrome-
chnical systems (MEMS). Methods of micromachin-
ing and how these methods can be used to produce microstructures, micro-
sensors, and microactuators. Students design micro-
fabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM520A. Letter grading.

Mr. Chiu (Fall, Winter, Spring)

CM180L. Introduction to Micromachining and Mi-
croelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM150L and Electrical Engineering CM150L.) Lecture, one hour; laboratory, one hour; outside study, one hour. Requisites: course CM180, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to microma-
chinching technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachin-
ing and how these methods can be used to produce variety of MEMS, including microstructures, micro-
sensors, and microactuators. Students design micro-
fabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM280L. Letter grading.

Mr. Chiu (Fall, Winter, Spring)

181A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 182A. Complex variables, analytic functions, conformal mapping, contour inte-
grals, singularities, residues, Cauchy integrals; La-
place transform: properties, convolution, inversion; Fourier transform; properties, convolution, FFT, appli-
cations in dynamical systems, structures, and heat conduction. Letter grading.

Mr. Ghoniem (Not offered 2013-14)

182A. Mathematics of Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 110A and 110B. Methods of solving ordinary differential equations in engineer-
ing. Review of matrix algebra. Solutions of systems of first- and second-order ordinary differential equa-
tions. Design of Laplace transforms and their application to ordinary differential equations. Intro-
duction to boundary value problems. Nonlinear differ-
e ntial equations and stability. Letter grading.

182B. Mathematics of Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 182A. Analytical methods for solving partial differential equations aris-
ing in engineering. Separation of variables, eigen-
value 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. Let-
ter grading.

Mr. Eldredge, Mr. J. Kim (Winter)

182C. Numerical Methods for Engineering Appli-
cations. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 182A, Computer Science 31. Recommended: Electro-
rical Engineering 103. Basic topics from numerical analysis having wide application in solution of practi-
cal engineering problems, computer arithmetic, and errors. Solution of linear and nonlinear systems. Alge-
braic eigenvalue problem. Least-square methods, numerical quadrature, and finite difference approxi-

Mr. Zhong (Fall)

183. Introduction to Manufacturing Processes. (4) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisite: Materials Sci-
ence 104. Manufacturing fundamentals. Materials in manufacturing. Manufacturing systems. Rapid proto-
typing, Material removal processes, Solidification and forming. Joining and assembly. Particulate and sur-

Mr. C.-J. Kim (Winter, Spring)

184. Introduction to Geometry Modeling. (4) Lecture, four hours; laboratory, four hours; outside study, four hours; outside work, one hour. Lecture, one hour; outside study, six hours. Enforced requisite: Materials Science 31. Fundamentals in parametric curve and surface modeling, parametric spaces, blending functions, cones, splines and Bezier curve, coordinate transforma-
tions, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and im-
plementation. Letter grading.

Mr. Gad (Not offered 2013-14)

185. Introduction to Radio Frequency Identifica-
tion and Its Application in Manufacturing and Supply Chain. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requi-
site: Computer Science 31. Manufacturing today re-
quires assembling of individual components into as-
sembled products, shipping of such products, and eventual handling and sale of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and as-
semblies of products allow them to be tracked auto-
matically as they move and transform through manu-
facturing supply chain. RFID tags have memory and small CPU that allows information about product sta-
tus to be written, stored, and transmitted wirelessly. Tags can then be integrated into electronic systems by enter-
prise software by way of RFID middleware layer. Study of how RFID is being utilized in manufacturing, with focus on automotive and aerospace. Letter grading.

Mr. Gad (Not offered 2013-14)

C187L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and bio-
 logical principles related to these techniques, top-
down and bottom-up (self-assembly) nanofabrica-
tion, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students en-
roll to create their own projects in small, self-designed experiments. Concurrently scheduled with course C287L. Letter grading.

Mr. Y. Chen (Fall, Spring)

188. Special Courses in Mechanical and Aero-
space Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Special top-
ics in mechanical and aerospace engineering for un-
dergraduates taught on experimental or tem-
porary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. P/NP or letter grading.

(Not offered 2013-14)

194. Research Group Seminars: Mechanical and 
Aerospace Engineering. (1 to 4) Lecture, one hour; outside study, four to eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of proj-
ects in research specialty. May be repeated for credit. P/NP or letter grading.

199. Directed Research in Mechanical and Aero-
space Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual re-
search or investigation under the personal direction of a faculty mentor. Culminating paper or project required. May be repeated for credit with topic approval. Individu-
al contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.

(Fall, Winter, Spring)

Courses Graduate

231A. Convective Heat Transfer Theory. (4) Lecture, four hours; outside study, eight hours. Requi-
sites: courses 131A, 128B. Recommended: course 250A. Conservation equations for flow of real fluids. Analysis of heat transfer in laminar and turbulent, in-
compressible and compressible flows. Internal and exter-
nal flows; free convection. Variable wall temper-
ature; effects of variable fluid properties. Analogy

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150D. Radiative properties of materials and radiative ener-
gy transfer. Emphasis on fundamental concepts, in-
cluding energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiative transfer in absorbing, emit-
ting, and scattering media. Applications cover laser-
material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading.

Ms. Lavine (Winter)

231C. Phase Change Heat Transfer and Two-
Phase Flow. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Two-
phase flow, boiling, and condensation. Generalized

fraction and interference. Fourier optics, beam op-
tics. Propagation of light, Snell's law, and Huygen 
principles. Diffraction and interference. Fourier trans-
forms and their application to optical devices, waves, 
spherical waves, and image formation. Total internal 
reflection. Polarization, polarizers, and wave-plates. 
Lenses and aberrations, lens laws and formation of 
images, resolution and primary aberrations. Simple 
or complex instruments, their characteristics. Design 
of telescopes, microscope design, projection system 
design. Interference, Young's slit experiment and 
fringe visibility, Michelson interferometer, multi-
ple-beam interference and thin film coatings. Diffra-
tion theory, Fraunhofer and Fresnel diffraction, Fres-
nel zone plate. Fiber optics, waveguides and modes, 
fiber coupling, types of fiber: single and multimode. 

Letter grading.

Mr. Chiu (Not offered 2013-14)
constitutive equations for two-phase flow. Phenome-
nological theories of boiling and condensation, in-
cluding forced flow effects. Letter grading. Mr. Catton (F)

231G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electronics, phonons, etc.). 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)

C232A. Mass Transport. (4) Lecture; four hours; out-
side study, eight hours. Requisites: courses 105D, 131A. Principles of mass transfer by diffusion and convection. Applications and mathematical models. Transport in multicomponent systems. Thermal, forced, and pressure diffusion, Brownian diffusion. Analysis of evaporative and transpiration cooling, catalysis, and combustion. Mass exchangers, including automobile catalytic converters, electrostatic precipi-
tators, filters, scrubbers, humidifiers, and cooling towers. Concurrently scheduled with course C132A. Letter grading. Mr. Plochocki (W)

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 182A. Underlying physics and mathematics of nucle-
ar reactors: reactor design. Diffusion theory, reac-
tor kinetics, slowing down and thermalization, multi-
group methods, introduction to transport theory. Let-
ter grading. Mr. Abdou

M237B. Fusion Plasma Physics and Analysis. (Same as Electrical Engineering M287) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering M185. Fundamentals of plasmas at thermionic burning conditions. Fokker/Planck equation and applications to heating by neutral beams, RF, and fusion reaction products. Brems-
strahlung, synchrotron, and atomic radiation pro-
cesses. Plasma surface interactions. Fluid descrip-
tion of plasmas. Hydrodynamic stability, control, and con-
trol. Applications in tokamaks, tandem mirrors, and alternate concepts. Letter grading. Mr. Abdou

237D. Fusion Engineering and Design. (4) Lecture, four hours; outside study, eight hours. Fusion reaction-
tions and fuel cycles. Principles of inertial and mag-
netic fusion. Plasma requirements for controlled fu-
sion. Plasma-surface interactions. Fusion reactor concepts and technological components. Analysis of equilibrium and nonequilibrium plasmas, conversion and tritium breeding components, radia-
tion shielding, magnets, and heating. Letter grading. Mr. Abdou

239B. Seminar: Current Topics in Transport Pheno-
onena. (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 proj-
ects in areas of current interest in transport phenom-
enon. 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 study and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measurement techniques. May be repeated for credit with topic change. S/U grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear ma-
terials, and reactor design. May be repeated for credit with topic change. S/U grading.

239H. Special Topics in Fusion Physics, Engineer-
ing, and Technology. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced treatment of subjects selected from research areas in fusion science and engineer-
ing, such as instabilities in burning plasma, alternate fusion concepts and key technologies, fusion reac-
tion, fusion-fission hybrid systems, and fusion reac-
tor safety. May be repeated for credit with topic change. S/U grading.

2540. Introduction to Biomechanics. (Same as Genetics M176E) Lecture, four hours; dis-
cussion, two hours; outside study, six hours. Requir-
sites: courses 101, 102, 105A. Introduction to me-
chanical functions of human body; skeletal adapta-
tions to load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applica-
tions. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading. Mr. Gupta (W)

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Corequisite: course 182B. Development and application of fundamental principles of flu-
id mechanics at graduate level, with emphasis on un-
compressible flow. Flow kinematics, basic equations, constitutive relations, exact solutions on the Navier/ Stokes equations, decomposition of flow fields, potential flow. Letter grading. Mr. Eldredge, Mr. J. Kim (W)

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, six hours. Requisite: course 150A. Fundamental principles of fluid dynam-
ics applied to study of fluid resistance. States of fluid motion discussed in order of advancing Reynolds number; wakes, boundary layers, instability, transi-
tion, and turbulent shear flows. Letter grading. Mr. Eldredge, Mr. J. Kim (W)

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Effects of compressibility in viscous and invisi-
cid flows. Steady and unsteady inviscid subsonic and supersonic flows; method of characteristics; small disturbance theories (linearized and hypersonic); shock dynamics. Letter grading. Mrs. John, Mr. C. Fred, Mr. Zhong (F)

Mrs. Karagopian, Mr. Zhong (F)

250D. Computational Aerodynamics. (4) Lecture, four hours. Requisites: courses 150A, 150B, 182C. Introduction to useful methods for computation of aerodynamic flow fields. Coverage of potential, Euler, and Navier/Stokes equations for subsonic to hyper-
sonic speeds. Letter grading. Mr. Zhong

250E. Spectral Methods in Fluid Dynamics. (4) Lecture, four hours; outside study, six hours. Requir-
isites: courses 182A, 182B, 182C, 250A, 250B. In-
troduction to basic concepts and techniques of vari-
ious spectral methods applied to solving partial diffe-
rential equations. Particular emphasis on techniques of solving unsteady three-dimensional Navier/Stokes equations. Topics include spectral representation of functions, discrete Fourier transform, etc. Letter grading. Mr. J. Kim

250F. Hypersonic and High-Temperature Gas Dy-
namics. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 250C. Molec-
ular and chemical description of equilibrium and non-
equilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical ther-
modynamics for calculation gas properties, equilibri-
um flows of real gases, vibrational and chemical rate processes, nonequilibrium flows of real gases, and computational fluid dynamics methods for nonequilib-
rium hypersonic flows. Letter grading. Mr. Zhong

250G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requir-
isites: courses 182A, 182B, 182C, 250A, 250B. Un-
tivelocity flows, free-shear flows, wall-bounded flows, turbu-

cence modeling, numerical simulations of turbulent flows, and turbulence control. Letter grading. Mr. J. Kim (Sp)

252C. Fluid Mechanics of Combustion Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Recommended requisite: course 250C. Review of fluid mechanics and chem-
ical thermodynamics applied to reactive systems, laminar diffusion flames, premixed laminar flames, thermal explosion, flames and flows, unsteady combustion, supercritical stability, ignition, turbulent combustion, supersonic combustion. Letter grading. Mrs. Karagopian

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics; molecular collisions, distribution functions and aver-
aging, semiempirical and ab initio potential surfaces, trajectory calculations, statistical reaction rate theo-
ries. Practical examples of large-scale chain mecha-
nisms from combustion chemistry of several ele-
ments, etc. Letter grading. Mrs. Karagopian

254A. Special Topics in Aerodynamics. (4) Lecture, for graduate students and outside study, eight hours. Requisites: courses 150A, 150B, 182A, 182B, 182C. Special top-
ics of current interest in advanced aerodynamics. Ex-
amples include transonic flow, hypersonic flow, sonic booms, and unsteady aerodynamics. Letter grading. Mr. Gibson (Sp)

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 189A. Variational principles and Lagrange equations. Kinematics and dynamics of rigid bodies; procession and nutation of spinning bodies. Letter grading.

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requir-
isite: course 255A. Concepts of stability; state-
space interpretation; stability determination by simu-
ation, linearization, and Lyapunov direct method; the Hamiltonian as a Lyapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and nonlin-
ear resonance. Application to mechanical systems. Letter grading. Mr. M’Closkey

M256A. Linear Elasticity. (4) (Same as Civil Engi-
nering M256A) Lecture, four hours. Requisite: course 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibri-
um equations; linear constitutive relations; elastic plane elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Bou-
sinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading. Mr. M (F)

Mechanical and Aerospace Engineering / 105


264. Elasticity Dynamics. (Same as Earth and Space Sciences M224A.) Lecture, four hours; outside study, eight hours. Requisite: 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.

255A. Nanomechanics and Micromechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materials at scales ranging from atomic through microstructure or transitional and up to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics, Langevin dynamics, and kinetic Monte Carlo) and their applications at nanoscale. Development and implementation of analytical and statistical mechanics methods in areas of nanostucture and microstructure self-organization, heterogeneous plastic deformation, material instabilities, and failure phenomena. Incorporation of techniques and applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultrasonic nanolayer materials), nano-identification, smart (active) materials, nanobending and microbending, and torsion. Letter grading. Mr. Ghoniem.

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study of topics in fluid mechanics, with intensive student participation involving assignments in class leading to term paper or oral presentation (possible help from guest lecturers). Letter grading. Mr. Kavehpour (W).

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 structures. Letter grading. Mr. Mal.

260. Current Topics in Mechanical Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, and student presentations and projects in areas of current interest in mechanical engineering. May be repeated for credit. S/U grading.


M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engineering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course 171A or Electrical Engineering M240C. Introduction to time-invariant (LTI) and time-variying (LTV) systems in continuous and discrete time. Linear algebra concepts such as eigenvectors and eigenvalues, singular values, Cayley/Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and observers; separation principle and Kalman filter. Letter grading. Mr. Gibson (W).

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A. Optimal control problems for linear time-invariant systems, uncertainty of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stability, observability, and detectability. Letter grading. Mr. M'Closkey (F).

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

271A. Probability and Stochastic Processes in Dynamical Systems. (4) (Formerly numbered 271A.) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 107, 182, Probability, random variables, stochastic sequences and processes. Introduction to Gaussian/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C175A. Letter grading. Mr. Speyer (W).

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W).


271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminars on current research topics in dynamical systems and their applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer.

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M282A and Electrical Engineering M242A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. State-space techniques for studying solutions of
time-invariant and time-varying nonlinear dynamic systems with emphasis on stability. Lapunov theory (including Lyapunov functions), invariance, center manifold theorem, input-to-state stability and small gain theorem. Letter grading.

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: CM135A. Advanced discussion of modern control systems design, stochastic processes, and random processes. Students design control systems using modern control theory to achieve desired performance. Letter grading.

273B. Dynamic Programming. (4) (Same as Electrical Engineering M252A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 171F, M270A. Graduation-level introduction to analysis and design of multivariable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representation, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading.

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 continuous 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 structure, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading.

Mr. Gibson (Sp)

M276. Dynamic Programming. (4) (Same as Electrical Engineering M252A.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 171B, M270A. Digital signal processing and control analysis of mechatronic systems. System inversion-based digital control algorithms and robustness properties, Youla parameterization of stabilizing controllers, previewed optimal feedback compensator, repetitive and learning control, and adaptive control. Real-time control investigation of topics to selected mechatronic systems. Letter grading. Mr. Tai (Sp)

279. Dynamics and Control of Biological Oscillations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 107, M270A. Analysis and design of dynamical mechanisms underlying biological control systems that generate coordinated oscillations. Applications of information processing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, optimal gait (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading.

Mr. Iwasaki (Sp)

CM280A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Same as Bioengineering CM250A and Electrical Engineering CM250A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to 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 micromachining processes capable of achieving desired MEMS device. Concurrently scheduled with course CM180. Letter grading.

Mr. Chih (F)

CM280B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M250B and Electrical Engineering M250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course CM180 or CM290A. 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. J. Kim

CM280L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory, (2) (Same as Bioengineering CM250L and Electrical Engineering CM250L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM280A. Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Students study processes in practicing micromachining laboratory, two hours. Concurrently scheduled with course CM180L. Letter grading.

Mr. Chih (F)

281. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Basic science issues in micro domain. Topics include micro fluid science, microscale heat transfer, mechanical behavior of microstructures, as well as dynamics and control of micro devices. Letter grading.

Mr. Ho, Mr. C-Y. Kim (F)

M282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Bioengineering M252 and Electrical Engineering M252.) Lecture, four hours; discussion, one hour. 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. Chih (W)


Mr. Ho (W)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 103, 105A, 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 thermo-dynamics, and interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, interfacial tension, and flotation. Letter grading.

Mr. Pilon


Mr. Chih

M287. Nanoscience and Technology. (4) (Same as Electrical Engineering M257F.) Lecture, four hours; outside study, eight hours. Requisites: course CM280A. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanoscale devices, top-down and bottom-up (self-assembly) nanofabrication; nanocharacterization; nanomaterials, nanoelectronics, and nanobiotechnology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading.

Mr. Chen (W)

287L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (5) Lecture, two hours; laboratory, two hours; outside study, eight hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up micromachining, nanofabrication, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical biosensors. Students encouraged to create their own ideas in self-designed experiments. Concurrently scheduled with course C187L. Letter grading.

Mr. Y. Chen (Sp)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 104, Physics 17. Science and engineering of laser-based fabrications of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (therma, mass, chemistry, photonics), etc. in laser microfabrication, state-of-art optics and instrumentation for laser microfabrication, applications such as rapid prototyping, surface modifications (physical/chemical), microchips for three-dimensional MEMS (microelectromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter grading.


Mr. Ghorien

294. Computational Geometry for Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisites: course 184. 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 manufacturing and current research topics in computational geometry for CAD/CAM systems. Letter grading.

Mr. Ghorien

295B. Internet-Based Collaborative Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 94, 184. Exploration of advanced state-of-the-art concepts in Internet-based collaborative design, including software environments to connect designers over Internet, networked variable media graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mobile device-based systems, and multidisciplinary design and software tools to support it. Letter grading.

Mr. Gach

295C. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading.

Mr. Gach

296A. Damage and Failure of Materials in Mechanical Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course 156A. Role of failure prevention in mechanical design and case studies. Mechanics and physics of material imperfections.

Mr. Ghoniem (F)

296B. Thermochemical Processing of Materials. (4) Lecture; four hours; outside study, eight hours. Requisite: course 183. Thermodynamics, heat and mass transfer, principles of material processing: phase equilibria and transport, separation, reaction mechanisms of heat and mass, moving interfaces and heat sources, natural convection, nucleation and growth of microstructure, etc. Applications with chemical vapor deposition, infiltration, etc. Letter grading.

Mr. Ghoniem, Ms. Lavine


Mr. Ghoniem

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.

F(Sp)

M299A. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M287 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.

May be repeated with topic change. Letter grading.

Ms. Lavine (F,Sp)

495. Teaching Assistant Training Seminar. (2) Seminar, two hours; outside study, four hours. Preparation: appointment as teaching assistant in department. Seminar on communication of mechanical and aerospace engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading.

Ms. Lavine (F,Sp)

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

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

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

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

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

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

Master of Science in Engineering Online Program

UCLA
7440 Boelter Hall
Box 951594
Los Angeles, CA 90095-1594

(310) 825-6542
fax: (310) 825-3081
http://msol.ucla.edu

Jenn-Ming Yang, Ph.D., Associate Dean

Scope and Objectives

The primary purpose of the Master of Science in Engineering online degree program is to enable employed engineers and computer scientists to augment their technical education beyond the Bachelor of Science degree and to enhance their value to the technical organizations in which they are employed.

The training and education that the program offers are of significant importance and usefulness to engineers, their employers, California, and the nation. It is at the M.S. level that engineers have the opportunity to learn a specialization in depth, and those engineers with advanced degrees may also renew and update their knowledge of the technology advances that continue to occur at an accelerating rate.

The M.S. program is addressed to those highly qualified employed engineers who, for various reasons, do not attend the on-campus M.S. programs and who are keenly interested in developing up-to-date knowledge of cutting-edge engineering and technology.

Graduate Study

For information on graduate admission, see Graduate Programs, page 22.

The following introductory information is based on the 2013-14 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasaa/library/pgmrqrintro.htm. Students are subject to the degree requirements as published in Program Requirements for the year in which they enter the program.
M.S. in Engineering Online Program

Course Requirements

The program consists of nine courses that make up a program of study. At least five courses must be at the 200 level, and one must be a directed study course. The latter course satisfies the University of California requirement for a capstone event (in the on-campus program the requirement is covered by a comprehensive examination or a thesis); the directed study course consists of an engineering design project that is better suited for the working engineer/computer scientist.

The program is structured in a manner that allows employed engineers/computer scientists to complete the requirements at a part-time pace (e.g., one 100/200-level course per term). Courses are scheduled so that the program can be completed within two academic years plus one additional term.

Advanced Structural Materials

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Director; jyang@seas.ucla.edu

The program provides students with a broad knowledge of advanced structural materials. Courses cover fundamental concepts of science and engineering of lightweight advanced metallic and composite materials, fracture mechanics, damage tolerance and durability, failure analysis and prevention, nondestructive evaluation, structural integrity and life prediction, and design of aerospace structures. Students are required to complete a project on a topic related to structural materials.

Aerospace Engineering

Xiaolin Zhong, Ph.D. (Mechanical and Aerospace Engineering), Director; xiaolin@seas.ucla.edu

The main objective of the program is to provide students with broad knowledge of the major technical areas of aerospace engineering to fulfill the current and future needs of the aerospace industry. Major technical areas include aerodynamics and computational fluid dynamics (CFD), systems and control, and structures and dynamics. Courses cover fundamental concepts of science and engineering of aerodynamics, compressible flow, computational aerodynamics, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, and dynamics of structures. Through a graduate course, students also gain skills in the development and application of CFD codes for solving practical aerospace problems.

If students have taken Mechanical and Aerospace Engineering 150B, 154B, and 171B or the equivalent at their undergraduate institutions, they can take other online-offered courses, approved by the area director, as substitute courses. In addition, students are required to complete a project on a topic related to the three major areas of this program.

Computer Networking

Mario Gerla, Ph.D. (Computer Science), Director; gerla@cs.ucla.edu

Three undergraduate elective courses complement the basic knowledge of the undergraduate electrical engineering or computer science degree with concepts in security, sensors, and wireless communications. The graduate courses expose students to key applications and research areas in the network and distributed systems field. Two required graduate courses cover the Internet and emerging sensor embedded systems. The electives probe different applications domains, including wireless mobile networks, security, network management, distributed P2P systems, and multimedia applications.

Electronic Materials

Ya-Hong Xie, Ph.D. (Materials Science and Engineering), Director; yhx@ucla.edu

The electronic materials program provides students with a knowledge set that is highly relevant to the semiconductor industry. The program has four essential attributes: theoretical background, applied knowledge, exposure to theoretical approaches, and introduction to the emerging field of microelectronics, namely organic electronics. All faculty members have industrial experience and are currently conducting active research in these subject areas.

Integrated Circuits

Dejan Markovic, Ph.D. (Electrical Engineering), Director; dejan@ee.ucla.edu

The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signaling and synchronization, VLSI signal processing, and communication system design. Summer courses are not yet offered in this program; therefore it cannot currently be completed in two calendar years.

Manufacturing and Design

Daniel C.H. Yang, Ph.D. (Mechanical and Aerospace Engineering), Director; dyang@seas.ucla.edu

The manufacturing and design program covers a broad spectrum of fundamental and advanced topics, including mechanical systems, digital control systems, microdevices and nanodevices, wireless systems, failure of materials, composites, and computational geometry. The program prepares students with the higher educational background that is necessary for today’s rapidly changing technology needs.

Mechanics of Structures

Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Director; ajit@seas.ucla.edu

The mechanics of structures program provides students with the knowledge required for the analysis and synthesis of modern engineered structures. The fundamental concepts of linear and nonlinear elasticity, plasticity, fracture mechanics, finite element analysis, and mechanics of composites and structural vibrations are developed in a series of undergraduate and graduate courses. These concepts are then applied in solving industry-relevant problems in a number of graduate-level courses. Students develop hands-on experience in using finite element packages for solving realistic structural analysis problems.

Signal Processing and Communications

Kung Yao, Ph.D. (Electrical Engineering), Director; yao@ee.ucla.edu

The program provides training in a set of related topics in signal processing and communications. Students receive advanced training in multimedia systems from the fundamentals of media representation and compression through transmission of signals over communications links and networks.

System Engineering

Peter S. Pao, Ph.D. (Computer Science), Director; peterspao@ucla.edu

System engineering has broad applications that include software, hardware, materials, and electrical and mechanical systems. A set of four core courses is offered that form the foundation of the system engineering program. The sequence of courses is designed for working professionals who are faced with design, development, support, and maintenance of complex systems.

For students who already hold an M.S. degree, a separate certificate of completion of the system engineering program can be earned by completing three of the core courses. See http://msengrol.seas.ucla.edu/areas-of-study for further information.
Schoolwide Programs, Courses, and Faculty

UCLA
6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
(310) 825-9580
http://www.engineer.ucla.edu

Professors Emeriti
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 22.

Faculty Areas of Thesis Guidance
Professors Emeriti
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 courses and their use in planning and management of projects and systems

Lower Division Courses
10A. Introduction to Complex Systems Science. (Formerly numbered M10A.) Lecture, four hours. How macroscopic patterns emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control. Such emergent order, whose explanation cannot be reduced to explanations at level of individual entities, is ubiquitous in biology and human social collectives, but also exists in certain physical processes such as earthquakes and some chemical reactions. Complexity also deals with how such systems undergo sudden changes, including catastrophic breakdowns, in absence of external force or central influence. Key aspect of biological and social collectives is their nature as complex adaptive systems, where individuals and groups adjust their behavior to external conditions. In biological and social systems, complexity science goes beyond traditional mathematics and statistics in its use of multigament computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading. Mr. Bragin (F).

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

87. Introduction to Engineering Disciplines. (4) 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 freshman seminars. Enrolled students may continue their current effort to increase participation of historically underrepresented groups in U.S. technological workforce. Letter grading. Mr. Wesel (F).

95. Internship Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to freshmen/sophomore students. Internship studies course supervised by associate dean or designated faculty member. Further supervision to be provided by organization for which students are doing internship. Professional and ethical considerations. Internship study credit for freshmen/sophomore students to count good jobs and achieve career success. P/NP grading. Mr. Wesel (F).

M101. Principles of Nanoscience and Nanotechnology. (4) Same as Materials Science M101. Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 10A, 20B, Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanometer) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electrical transport, structural stability, self-assembly, templated assembly and applications of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes. Letter grading. Mr. Ozolins (F).

102. Synthetic Biosystems and NanoSystems Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course M101, Life Sciences 3. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems, where biological components are reengineered and rewired to perform desirable functions in both intracellular and cell-free environments. Discussions of basic technologies and systems analysis that deal with dynamic behavior, noise, and uncertainties. Design project in which students are challenged to design novel biosystems and nanosystems for non-trivial task required. Letter grading. Mr. Liao (F).

M103. Environmental Nanotechnology: Implications and Applications. (4) Same as Materials Science M103. Lecture, four hours; discussion, two hours; outside study, six hours. Enrolled requisite: course M101. Introduction to potential implications of nanotechnology to environmental protection, including application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: physical, chemical, and biological properties; water and waste transport, reactivity, and toxicity of nanoscale materials in natural environmental systems; and use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Mr. Hoek (Sp).

110. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamental principles of micro-level (individual, firm, and industry) and macro-level (government, international) economics as they relate to technology management. How individuals, firms, and governments impact successful commercialization of high technology products and services. Letter grading. Mr. Monbouquette (F,Sp).

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of entrepreneurship, finance, human resources, and accounting disciplines as they impact management of technology commercialization. Topics include intellectual property management, team building, market forecasting, and entrepreneurial financing. Students work in small teams studying technology management plans to bring new technologies to market. Students select from set of available technology concepts, many generated at UCLA, that are in need of plans for movement from laboratory to market. Letter grading. Mr. Monbouquette (W,Sp).

113. Product Strategy. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enrolled requisite: M102. Enrolled as juniors/seniors. Described as an introduction to current management concept of product development. Topics include product strategy, product platform, and product line; competitive strategy, vectors of differentiation, product pricing, first-to-market versus fast follower; growth strategy, growth through acquisition, and new ventures; product portfolio management. Case studies, class projects, and guest lectures and discussions, and guest lectures by speakers from industry. Letter grading. Mr. Pao (W).

180. Engineering of Complex Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/seniors. Holistic view of engineering discipline, covering life-cycle of engineering, processes, and techniques used in industry today. Multidisciplinary systems engineering perspective in which aspects of electrical, mechanical, material, and software engineering are incorporated. Three specific case studies in communication, sensor, and processing systems included to help students understand these concepts. Special attention paid to link material covered to engineering curriculum offered by UCLA to help students integrate and enhance their understanding of knowledge already acquired. Motivational lectures continue their learning and reinforce lifelong learning habits. Letter grading. Mr. Wesel (Sp).

185EW. Engineering and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enrolled requisite: English Composition 3 or 3H or English as a Second Language 36. Not open for credit to students with credit for course 185EW. Limited to sophomore/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. Emphasis on research and writing within engineering environments. Writing and revision of about 20 pages total, including two individual technical essays and one team-written research report. Readings address
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.

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.

202. Reliability, Maintainability, and Supportability. (4) Lecture, four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with one to two years experience. Integration of Reliability, Maintainability, and Supportability with integration of other engineering systems is major driver of system life-cycle cost and key element of system engineering activities. Overview of engineering disciplines critical to this function—reliability, maintainability, and supportability—form relationships, taught using probability theory. Topics also include fault detections and isolations and parts obsolescence. Discussion of 6-sigma process, one effective design and manufacturing methodology, to ensure system reliability, maintainability, and supportability. Letter grading.

203. System Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with B.S. degrees in engineering or science and one to two years work experience in industry. Introduction to architecture methodolo-
gy—paradigm and tools. Principles of architecture through analysis of architecture designs of major existing systems. Discussion of selected elements of architectural practices, such as representation models, design progression, and architecture frame-
works. Examination of professionalization of system architecture. Letter grading.

204. Trusted Systems Engineering. (4) Lecture, four hours. Trust is placed in information systems to behave properly, but cyber threats and breaches have become routine, including penetration of financial, medical, government, and national security systems. To build systems that can protect confidentiality, integrity, and availability involves more than comp-
posing systems from network security, computer security, data protection, cryptography, etc. One can use most secure components, and resulting system could still be vulnerable. Skills learned ensure that systems are architected, designed, implemented, tested, and verified at all levels of trust. As-
pects include assessing vulnerability and risk for sys-
tems, establishing protection principles, and using them as guide to formulate system architectures; translating architectural design and verify-
ing correctness of design; and constructing and fol-
lowing trusted development and implementation Process letter grading.

215. Entrepreneurship for Engineers. (4) Lecture, four hours. Limited to graduate engineering students. Topics in starting and developing high-tech enterpris-
es and intended for students who wish to comple-
t their technical education with entrepreneurship. Letter grading.

299. Capstone Project. (4) Activity, 10 hours. Prepa-
ration: completion of minimum of four 200-level courses in online M.S. program. Project course that satisfies UCLA final comprehensive examination re-
quirement of M.S. degree in Engineering. Project is completed under individual guidance from UCLA Engineering faculty member. Incorporates advanced knowledge learned in M.S. program of study. Letter grading.

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

470A-470D. Engineer in Technical Environment, (3) Lecture, three hours. Limited to Engineering Executive Program students. Theory and application of quantitative methods in analysis and synthesis of engineering systems for purpose of making manage-
ment decisions. Optimization of outputs with respect to dollar costs, time, material, energy, information, and manpower. Case studies and individual projects. S/U grading.

471A-471B-471C. Engineer in General Environment. (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engi-
nering Executive Program students. Influences of human relations, law, 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 resisted and operated in specific technical environment. In Progress (471B) and S/U or letter (471C) grading.

472A-472D. Engineer in Business Environment. (3-
3-3) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engi-
nering Executive Program students. Language of business for engineering executive. Accounting, fi-
nance, business economics, business law, and mar-
keting. Laboratory in organization and management problem solving. Analysis of actual business prob-
lems 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 Large Scale Systems. (3-3) Lecture, two and one-half hours. Limited to Engineering Executive Program stu-
dents. Problem area of major industry or govern-
ment is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (473A) and S/U grading.

495A. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Lim-
ited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading. (F)

M495B. Supervised Teaching Preparation. (2) (Same as English Composition M495E) Seminar, two hours. Required of all teaching assistants for Engi-
nering writing courses not exempt by appropriate departamental or program training. Training and men-
toring, with focus on composition pedagogy, assess-
ment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, conducting peer reviews and conferences. S/U grading. (F,Sp)

M495C. Supervised Teaching Preparation. (2) (Same as English Composition M495F) Seminar, one hour. Requisite: course M495B. Required of all teach-
ing assistants in their initial term of teaching Engi-
nering writing courses. Mentoring in group and indi-
gual meetings. Continued focus on composition pedagogy, assessment of student writing, guidance of revision process, and specialized writing problems that may occur in engineering writing contexts. Practi-
cal concerns of preparing students to write course assignments, marking and grading essays, conducting peer reviews and conferences. S/U grading. (F,Sp)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate ad-
viser 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.
Center for Domain-Specific Computing
National Science Foundation Expedition in Computing Program
Jason Cong, PhD. (Computer Science), Director; http://www.cdsc.ucla.edu
To meet ever-increasing computing needs and overcome power density limitations, the computing industry has entered the era of parallelization, with tens to hundreds of computing cores integrated into a single processor and hundreds to thousands of computing servers connected in warehouse-scale data centers. However, such highly parallel, general-purpose computing systems still face serious challenges in terms of performance, energy, heat dissipation, space, and cost. The Center for Domain-Specific Computing (CDSC) looks beyond parallelization and focuses on domain-specific customization as the next disruptive technology to bring orders-of-magnitude power-performance efficiency improvement to important application domains.
CDSC develops a general methodology for creating novel customizable architecture platforms and the associated compilation tools and runtime management environment to support domain-specific computing. The proposed domain-specific customizable computing platform includes a wide range of customizable computing elements, from heterogeneous fixed cores to coarse-grain customizable cores and fine-grain field-programmable circuit fabrics; customizable high-performance radio frequency interconnects; highly automated compilation tools and runtime management software systems for application development; and a general, reusable methodology for customizable computing applicable across different domains. By combining these critical capabilities, the goal is to deliver a supercomputer-in-a-box that is customized to a particular application domain to enable disruptive innovations in that domain. This approach is being demonstrated in several important application domains in healthcare. The UCLA research is carried out as a collaborative effort between four universities: UCLA (lead institution), Rice University, UC Santa Barbara, and Ohio State University. The research team consists of a group of highly accomplished researchers with diversified backgrounds, including computer science and engineering, electrical engineering, medicine, and applied mathematics. CDSC offers many research opportunities for graduate students, and also provides summer research fellowship programs for high school and undergraduate students. The core funding for CDSC is provided by the National Science Foundation with a $10 million award from the 2009 Expedition in Computing Program. This program, established in 2008 by the NSF Directorate for Computer and Information Science and Engineering (CISE), provides the CISE research and education community with the opportunity to pursue ambitious, fundamental research agenda that promise to define the future of computing and information and to render great benefit to society.

Center for Function Accelerated nanoMaterial Engineering
Semiconductor Research Corporation (SRC) STARnet and Defense Advanced Research Projects Agency (DARPA) Researcher Center
Jane P. Chang, Ph.D. (Chemical and Biomolecular Engineering), Director; http://fame.nano.org
Research at the Center for Function Accelerated nanoMaterial Engineering (FAME) aims to incorporate nonconventional materials and nanostructures with their quantum properties for enabling analog, logic, and memory devices for non-Boolean computation. Its main focus is nonconventional material solutions ranging from semiconductors, dielectrics, and metallic materials as well as their correlated quantum properties. By creating and investigating these new atomic-scale engineered materials and structures, FAME will accelerate innovations in analog, logic, and memory devices for revolutionary impact on the semiconductor and defense industries.
The center focuses on prediction, growth, and multifunctional properties of nanoscale materials and structures to address broad research needs. Its four-theme strategy allows it to focus on metals, semiconductors, spintronic materials, atomic layered materials, and proto-typing; its discovery initiative allows it to fund projects based on recent discoveries within and outside the center to accelerate applications and further its own research.
FAME is one of six university-based STARnet research centers. FAME’s multi-university partnership includes 35 faculty researchers from 16 top U.S. universities. It will receive $6 million in SRC/DARPA funding.

Center for Translational Applications of Nanoscale Multiferroic Systems
National Science Foundation Engineering Research Center
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering), Director; Jane P. Chang, Ph.D. (Chemical and Biomolecular Engineering), Deputy Director; http://www.tanms.ucla.edu
Beyond development of revolutionary, miniature electromagnetic electronics by means of a new class of nanoscale multiferroic materials, the Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) seeks to increase its capacity for innovation by integrating its multidisciplinary research with commercialization and the fostering of lifelong skill development. It brings together domestic and international talents to stimulate their pursuit of engineering careers in the U.S. Its education program works with students in K-12, undergraduate, and postgraduate levels to instill a thirst for technological innovation and provide the appropriate entrepreneurial skills for long-term success in the engineering world.
TANMS seeks out the talents of individuals in every community through a compelling diversity strategy that aims at increasing participation from traditionally underrepresented groups in collaboration with source departments and schools, resulting in a diverse, inclusive environment for creative and innovative research.

Molecularly Engineered Energy Materials Energy Frontier Research Center
U.S. Department of Energy, Office of Science, Basic Energy Sciences
Vidvuds Ozolins, Ph.D. (Materials Science and Engineering), Director
The interdisciplinary Molecularly Engineered Energy Materials (MEEM) Energy Frontier Research Center (EFRC) was established in 2009 and brings together several faculty across the UCLA campus in close collaboration with scientists and faculty at the Department of Energy’s National Renewable Energy Laboratory, Eastern Washington University, the University of Kansas, and UC Berkeley. MEEM has active research programs on organic solar cells, electrochemical supercapacitors, and materials for carbon capture. MEEM focuses on materials that are inherently inexpensive (such as polymers, oxides, and metal-organic frameworks), can be eas-
ily assembled from intelligently designed building blocks (molecules, nanoparticles, and polymers), and have the potential to deliver transformative economic benefits in comparison with current crystalline- and polycrystalline-based energy technologies. A great deal of the center’s research is aimed at understanding the basic science issues in energy-related materials phenomena. These advances will enable rational design, efficient synthesis, and effective deployment of novel materials for energy applications. As global energy demands continue, the center’s work will be essential in helping to make alternative and renewable energy a viable resource for the 21st century.

Named Data Networking Project

National Science Foundation Future Internet Architecture (FIA) Program
Lixia Zhang, Ph.D. (Computer Science), Principal Investigator; http://www.named-data.net

While the Internet has far exceeded expectations, it has also stretched initial assumptions, often creating tussles that challenge its underlying communication model. Users and applications operate in terms of content, making it increasingly limiting and difficult to conform to IP’s requirement to communicate by discovering and specifying location. To carry the Internet into the future, a conceptually simple yet transformational architectural shift is required, from today’s focus on where—addresses and hosts, to what—the content that users and applications care about.

This project investigates a new Internet architecture called Named Data Networking (NDN). NDN capitalizes on strengths, and addresses weaknesses, of the Internet’s current host-based, point-to-point communication architecture in order to naturally accommodate emerging patterns of communication. By naming data instead of their location, NDN transforms data into a first-class entity. The current Internet secures the data container. NDN secures the contents, a design choice that de-couples trust in data from trust in hosts, enabling several radically scalable communication mechanisms such as automatic caching to optimize bandwidth. The project studies the technical challenges that must be addressed to validate NDN as a future Internet architecture: routing scalability, fast forwarding, trust models, network security, content protection and privacy, and fundamental communication theory. The project uses end-to-end testbed deployments, simulation, and theoretical analysis to evaluate the proposed architecture, and is developing specifications and prototype implementations of NDN protocols and applications.

Smart Grid Energy Research Center

Rajit Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director; http://smart-grid.ucla.edu
The UCLA Smart Grid Energy Research Center (SMERC) performs research, creates innovations, and demonstrates advanced wireless/communications, Internet, and sense-and-control technologies to enable the development of the next generation of the electric utility grid—the Smart Grid. SMERC also provides thought leadership through partnership between utilities, renewable energy companies, technology providers, electric vehicle and electric appliance manufacturers, DOE research labs, and universities, so as to collectively work on vision, planning, and execution towards a grid of the future. The Smart Grid of the future would allow integration of renewable energy sources, reduce losses, improve efficiencies, increase grid flexibility, reduce power outages, allow for competitive electricity pricing, allow for integration of electric vehicles, and overall become more responsive to market, consumer, and societal needs. SMERC is currently working on the topics of automated demand response, electric vehicle integration (G2V and V2G), microgrids, distributed renewable integration, storage integration into microgrids, cyber-security, and consumer behavior.

Western Institute of Nanoelectronics

Nanoelectronics Research Initiative National Institute of Excellence
Kang L. Wang, Ph.D. (Electrical Engineering), Director; http://win-nano.org
The Western Institute of Nanoelectronics (WIN), one of the world’s largest joint research programs focusing on spintronics, brings together nearly 30 eminent researchers to explore critically-needed innovations in semiconductor technology. A National Institute of Excellence, WIN leverages what are considered the best interdisciplinary nanoelectronics talents in the world to explore and develop advanced research devices, circuits, and nanosystems with performance beyond conventional CMOS devices. The pioneering new technology of spintronics relies on the spin of an electron to carry information, and holds promise in minimizing power consumption for next-generation electronics.

As rapid progress in the miniaturization of semiconductor electronic devices leads toward chip features smaller than 100 nanometers in size, researchers have had to begin exploring new ways to make electronics more efficient. Today’s devices, based on CMOS standards, cannot get much smaller and still function effectively.

Information-processing technology has so far relied on charge-based devices, ranging from vacuum tubes to million-transistor microchips. Conventional electronic devices simply move these electric charges around, ignoring the spin on each electron. Spintronics aims to put that extra spin action to work—effectively corralling electrons into one smooth chain of motion.

Wireless Health Institute

Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical Engineering), Majid Sarrafzadeh, Ph.D. (Computer Science), Co-Directors; http://www.wireless-health.ucla.edu

Advances in engineering and computer science are enabling the design of powerful home and mobile technologies that can augment functional independence and daily activities of people with physical impairments, disabilities, chronic diseases, and the accumulating impairments associated with aging. These home-health and mobile-health technologies can serve as monitors of health and activity, feedback reinforcement for risk factor management, and outcome measures for individual care and large clinical trials.

The Wireless Health Institute believes that tiny sensors—including accelerometers, gyroscopes, force transducers, and visual and sound recorders worn on the body and in clothing—will become essential components for the delivery of health care and health maintenance. Sensors created by micro- and nano-technologies will simplify communications with health providers seamlessly over Internet and WIFI transmission using telephones and other convenient devices. To pursue these applications, our collaboration includes the highly ranked UCLA schools of Medicine, Nursing, Engineering and Applied Science, and Management, the Clinical Translational Science Institute for medical research, the Ronald Reagan UCLA Medical Center, and faculty from many departments on campus.
# B.S. in Aerospace Engineering Curriculum

## Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure ........................................ 4</td>
</tr>
<tr>
<td></td>
<td>English Composition 3 — English Composition, Rhetoric, and Language ............................. 5</td>
</tr>
<tr>
<td></td>
<td>Mathematics 31A — Differential and Integral Calculus ............................................. 4</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory ............................. 7</td>
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<tr>
<td></td>
<td>Mathematics 31B — Integration and Infinite Series .................................................. 4</td>
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<tr>
<td></td>
<td>Physics 1A — Mechanics ........................................................................................................ 5</td>
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<tr>
<td>3rd Quarter</td>
<td>Mathematics 32A — Calculus of Several Variables ..................................................... 4</td>
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<tr>
<td></td>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields ................................... 5</td>
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<tr>
<td></td>
<td>Physics 4AL — Mechanics Laboratory .................................................................................. 2</td>
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<td>HSSEAS GE Elective* ......................................................................................................... 5</td>
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## Sophomore Year

<table>
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<tr>
<th>Quarter</th>
<th>Course Description</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Mathematics 32B — Calculus of Several Variables ..................................................... 4</td>
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<tr>
<td></td>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity .................................. 5</td>
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<tr>
<td></td>
<td>Physics 4BS — Electricity and Magnetism Laboratory .................................................. 2</td>
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<tr>
<td></td>
<td>HSSEAS Ethics Course ...................................................................................................... 4</td>
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<tr>
<td>2nd Quarter</td>
<td>Materials Science and Engineering 104 — Science of Engineering Materials ..................... 4</td>
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<tr>
<td></td>
<td>Mathematics 33A — Linear Algebra and Applications .................................................. 4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials ............. 4</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics ............................................................................................................................................ 4</td>
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<tr>
<td>3rd Quarter</td>
<td>Computer Science 31 — Introduction to Computer Science I .......................................... 4</td>
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<tr>
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<td>Mathematics 33B — Differential Equations ......................................................................... 4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics ............................. 4</td>
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## Junior Year

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<tr>
<th>Quarter</th>
<th>Course Description</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits ....................................... 4</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies ............................. 4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 182A — Mathematics of Engineering ............................. 4</td>
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<td>HSSEAS GE Elective* ......................................................................................................... 4</td>
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<tr>
<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems ............................................................................................................................................ 4</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 150A — Intermediate Fluid Mechanics ............................. 4</td>
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<td>Mechanical and Aerospace Engineering 157S — Basic Aerospace Engineering Laboratory .......... 4</td>
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<td>HSSEAS GE Elective* ......................................................................................................... 5</td>
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<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 150B — Aerodynamics ............................................. 4</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems .................................................................................................................................................. 4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 150R (Rocket Propulsion Systems)** or Aerospace Engineering Elective† ........................................................................................................................................... 4</td>
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<td>Technical Breadth Course* ................................................................................................. 4</td>
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## Senior Year

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<tr>
<th>Quarter</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Mechanical and Aerospace Engineering C150P — Aircraft Propulsion Systems ............................. 4</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 154S — Flight Mechanics, Stability, and Control of Aircraft ............................................................................................................................................. 4</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 161A (Introduction to Astronautics)** or Aerospace Engineering Elective† ........................................................................................................................................... 4</td>
</tr>
<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 166A — Analysis of Flight Structures ............................. 4</td>
</tr>
<tr>
<td>2nd Quarter</td>
<td>Mechanical and Aerospace Engineering 154A — Preliminary Design of Aircraft ............................. 4</td>
</tr>
<tr>
<td></td>
<td>Aerospace Engineering Elective† ......................................................................................... 4</td>
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<td>HSSEAS GE Elective* ......................................................................................................... 5</td>
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<td></td>
<td>Technical Breadth Course* ................................................................................................. 4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Mechanical and Aerospace Engineering 154B — Design of Aerospace Structures ............................. 4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 157A — Fluid Mechanics and Aerodynamics Laboratory .................................................................................................................................................. 4</td>
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<tr>
<td></td>
<td>Technical Breadth Course* ................................................................................................. 4</td>
</tr>
</tbody>
</table>

** Total: 187 **

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).**

** Either Mechanical and Aerospace Engineering 150R or 161A is required.**

† A total of 8 units of aerospace engineering electives (two courses) is required.
### B.S. in Bioengineering Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Bioengineering 10 — Introduction to Bioengineering</td>
<td>2</td>
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<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
<td>4</td>
</tr>
<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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</tr>
<tr>
<td>Mathematics 31A — Differential and Integral Calculus</td>
<td>4</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
<td>4</td>
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<tr>
<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Mathematics 31B — Integration and Infinite Series</td>
<td>4</td>
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<tr>
<td>Physics 1A or 1AH — Mechanics</td>
<td>5</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
<td>4</td>
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<tr>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td>Physics 1B or 1BH — Oscillations, Waves, Electric and Magnetic Fields</td>
<td>5</td>
</tr>
<tr>
<td>Physics 4AL — Mechanics Laboratory</td>
<td>2</td>
</tr>
</tbody>
</table>

### SOPHOMORE YEAR

| **1st Quarter** |       |
| Bioengineering 100 — Bioengineering Fundamentals | 4 |
| Life Sciences 2 — Cells, Tissues, and Organs | 4 |
| Mathematics 33A — Linear Algebra and Applications | 4 |
| Physics 4BL — Electricity and Magnetism Laboratory | 2 |
| **2nd Quarter** |       |
| Bioengineering 167L — Bioengineering Laboratory | 4 |
| Computer Science 31 — Introduction to Computer Science I | 4 |
| Mathematics 33B — Differential Equations | 4 |
| HSSEAS GE Elective* | 5 |

### JUNIOR YEAR

| **1st Quarter** |       |
| Bioengineering 165EW** — Bioengineering Ethics | 4 |
| Electrical Engineering 100 — Electrical and Electronic Circuits | 4 |
| Life Sciences 3 — Introduction to Molecular Biology | 4 |
| Life Sciences 23L — Introduction to Laboratory and Scientific Methodology | 2 |
| **2nd Quarter** |       |
| Bioengineering 120 — Biomedical Transducers | 4 |
| Chemistry and Biochemistry 30BL — Organic Chemistry Laboratory I | 3 |
| Life Sciences 4 — Genetics | 5 |
| HSSEAS GE Elective* | 5 |
| **3rd Quarter** |       |
| Bioengineering 110 — Biotransport and Bioreaction Processes | 4 |
| Bioengineering 176 — Principles of Biocompatibility | 4 |
| Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism | 4 |
| HSSEAS GE Elective* | 5 |

### SENIOR YEAR

| **1st Quarter** |       |
| Bioengineering C106 — Topics in Biophysics, Channels, and Membranes | 4 |
| Bioengineering 177A — Bioengineering Capstone Design I | 4 |
| Major Field Elective*/Technical Breadth Course* | 8 |
| **2nd Quarter** |       |
| Bioengineering 177B — Bioengineering Capstone Design II | 4 |
| Bioengineering 180 — System Integration in Biology, Engineering, and Medicine I | 4 |
| Major Field Elective*/Technical Breadth Course* | 8 |
| **3rd Quarter** |       |
| HSSEAS GE Elective* | 5 |
| Major Field Elective*/Technical Breadth Course* | 8 |

**TOTAL** 187

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).

** Satisfies the HSSEAS ethics requirement.

† Electives include Bioengineering C101, CM102, CM103, C104, C105, C131, CM140, CM145, C147, CM150, C170, C171, CM178, C179, 180L, 181, 181L, 199 (8 units maximum).
# B.S. in Chemical Engineering Curriculum

## FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mathematics 31A — Differential and Integral Calculus</td>
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**TOTAL** 186

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# B.S. in Chemical Engineering

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# B.S. in Chemical Engineering

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<td>Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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**TOTAL** 190

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).*
B.S. in Chemical Engineering
Semiconductor Manufacturing Engineering Option Curriculum

**FRESHMAN YEAR**

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<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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**SOPHOMORE YEAR**

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<td>Chemical Engineering 102B — Thermodynamics II</td>
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**JUNIOR YEAR**

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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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<td>Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism</td>
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**SENIOR YEAR**

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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Chemical Engineering 104C/104CL — Semiconductor Processing/Laboratory</td>
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<td>Chemical Engineering C116 — Surface and Interface Engineering</td>
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**TOTAL**

190

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Civil Engineering Curriculum

## FRESHMAN YEAR

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<td>Civil and Environmental Engineering 105 — Introduction to Computing for Civil Engineers</td>
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<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<td>Civil and Environmental Engineering 103 — Applied Numerical Computing and Modeling in Civil and Environmental Engineering</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Chemical and Aerospace Engineering 103 — Elementary Fluid Mechanics</td>
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<td>Civil and Environmental Engineering 150 — Introduction to Hydrology</td>
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**TOTAL** 189 or 190

*Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).

† Must include required courses for two of the major field areas listed on pages 45–46.
### FRESHMAN YEAR

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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td>Computer Science 33 — Introduction to Computer Organization</td>
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<td>Computer Science 111 — Operating Systems Principles</td>
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<td>Computer Science 131 — Programming Languages</td>
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<td>Computer Science M151B or Electrical Engineering M116C — Computer Systems Architecture</td>
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**TOTAL** 183

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Computer Science and Engineering Curriculum

**FRESHMAN YEAR**

<table>
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<tr>
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<th>Course</th>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>2nd</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td></td>
<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<td>3rd</td>
<td>Computer Science 33 — Introduction to Computer Organization</td>
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<td></td>
<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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**SOPHOMORE YEAR**

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<td>Computer Science 111 — Operating Systems Principles</td>
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**JUNIOR YEAR**

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<td>Electrical Engineering 102 — Systems and Signals</td>
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<td>Computer Science 131 — Programming Languages</td>
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<td>Computer Science M151B or Electrical Engineering M116C — Computer Systems Architecture</td>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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**SENIOR YEAR**

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**TOTAL**

189

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
# B.S. in Electrical Engineering Curriculum

### FRESHMAN YEAR

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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<tr>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 4AL — Mechanics Laboratory</td>
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### SOPHOMORE YEAR

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<td>Electrical Engineering 10 — Circuit Theory I</td>
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<tr>
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<tr>
<td>Mathematics 33B — Differential Equations</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Electrical Engineering 102 — Systems and Signals</td>
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<td>Electrical Engineering 103 — Applied Numerical Computing</td>
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<td>Mathematics 33C — Complex Analysis for Applications</td>
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### JUNIOR YEAR

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<td>Electrical Engineering 113 — Digital Signal Processing</td>
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<td>Electrical Engineering 131A — Probability</td>
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<td>Electrical Engineering 2 — Physics for Electrical Engineers</td>
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<td>Electrical Engineering 101B — Electromagnetic Waves</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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<td>Electrical Engineering 115A — Analog Electronic Circuits I</td>
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<td>Electrical Engineering 115AL — Analog Electronics Laboratory I</td>
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<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
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<td>Electrical Engineering 132A — Introduction to Communication Systems</td>
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### SENIOR YEAR

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**TOTAL** 189

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See page 74 for a list of approved pathways.
## B.S. in Electrical Engineering
### Biomedical Engineering Option Curriculum

### FRESHMAN YEAR

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<tr>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>Electrical Engineering 3 — Introduction to Electrical Engineering</td>
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### JUNIOR YEAR

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### SENIOR YEAR

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<td>Technical Breadth Course*†</td>
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<td>Mathematics 132 — Complex Analysis for Applications</td>
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† See page 74 for the biomedical engineering pathway.
# B.S. in Electrical Engineering

## Computer Engineering Option Curriculum

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<thead>
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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<tr>
<td>Mathematics 31B — Integration and Infinite Series</td>
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## SOPHOMORE YEAR

| 1st Quarter: | |
| Electrical Engineering 3 — Introduction to Electrical Engineering | 3 |
| Mathematics 32B — Calculus of Several Variables | 4 |
| Mathematics 33A — Linear Algebra and Applications | 4 |
| Physics 4AL — Mechanics Laboratory | 2 |
| 2nd Quarter: | |
| Electrical Engineering 10 — Circuit Theory I | 4 |
| Electrical Engineering M16 or Computer Science M51A — Logic Design of Digital Systems | 4 |
| Mathematics 33B — Differential Equations | 4 |
| Physics 1C — Electrodynamics, Optics, and Special Relativity | 5 |
| 3rd Quarter: | |
| Electrical Engineering 102 — Systems and Signals | 4 |
| Mathematics 132 — Complex Analysis for Applications | 4 |
| Physics 4Bl — Electricity and Magnetism Laboratory | 2 |
| HSSEAS Ethics Course | 4 |

## JUNIOR YEAR

| 1st Quarter: | |
| Computer Science 35L — Software Construction Laboratory | 2 |
| Electrical Engineering 101A — Engineering Electromagnetics | 4 |
| Electrical Engineering 110 — Circuit Analysis II | 4 |
| Electrical Engineering 113 — Digital Signal Processing | 4 |
| Electrical Engineering 131A — Probability | 4 |
| 2nd Quarter: | |
| Electrical Engineering 2 — Physics for Electrical Engineers | 4 |
| Electrical Engineering 110L — Circuit Measurements Laboratory | 2 |
| Electrical Engineering 115A — Analog Electronic Circuits I | 4 |
| Statistics 105 — Statistics for Engineers | 4 |
| 3rd Quarter: | |
| Electrical Engineering 103 — Applied Numerical Computing | 4 |
| Electrical Engineering 115C — Digital Electronic Circuits | 4 |
| HSSEAS GE Elective* | 4 |
| Pathway Course (Electrical Engineering 132A — Introduction to Communication Systems or Computer Science M117 — Computer Networks: Physical Layer) | 4 |

## SENIOR YEAR

| 1st Quarter: | |
| HSSEAS GE Elective* | 5 |
| Pathway Course (Computer Science 111 — Operating Systems Principles)† | 4 |
| Technical Breadth Course*/Pathway Laboratory Course† | 6 |
| 2nd Quarter: | |
| Electrical Engineering M116C or Computer Science M151B — Computer Systems Architecture | 4 |
| Pathway Course (Computer Science 131 — Programming Languages or 132 — Compiler Construction or 180 — Introduction to Algorithms and Complexity) | 4 |
| Technical Breadth Course*/HSSEAS GE Elective* | 9 |
| 3rd Quarter: | |
| Electrical Engineering 132B (Data Communications and Telecommunication Networks) or Computer Science 118 (Computer Network Fundamentals) | 4 |
| Pathway Design Course† | 4 |
| Technical Breadth Course*/HSSEAS GE Elective* | 9 |

**TOTAL** 190

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).

† See page 75 for the computer engineering pathway.
# B.S. in Materials Engineering Curriculum

## FRESHMAN YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Course Name</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</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>Materials Science and Engineering 10 — Freshman Seminar: New Materials</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Physics 1A — Mechanics</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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<tbody>
<tr>
<td>1st</td>
<td>Civil and Environmental Engineering 101 (Statics and Dynamics)</td>
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<td>Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)</td>
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<td>Mathematics 32B — Calculus of Several Variables</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>HSSEAS GE Elective</td>
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<td>3rd</td>
<td>Computer Science 31 — Introduction to Computer Science I</td>
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<td>Materials Science and Engineering 90L — Physical Measurement in Materials Engineering</td>
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<td>Mathematics Science and Engineering 33B — Differential Equations</td>
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## JUNIOR YEAR

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<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>Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Laboratory</td>
<td>6</td>
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<td>Materials Science and Engineering 130 — Phase Relations in Solids</td>
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<td>Materials Science and Engineering 120 — Physics of Materials</td>
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<td>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>Materials Science and Engineering 143A — Mechanical Behavior of Materials</td>
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<td>Technical Breadth Course</td>
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<td>3rd</td>
<td>Materials Science and Engineering 132 — Structure and Properties of Metallic Alloys</td>
<td>4</td>
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<td>Materials Engineering Electives (2)†</td>
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<td>Technical Breadth Course</td>
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</table>

## SENIOR YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Course Name</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Materials Science and Engineering 160 — Introduction to Ceramics and Glasses</td>
<td>4</td>
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<td>Mechanical and Aerospace Engineering 181A (Complex Analysis and Integral Transforms) or 182A (Mathematics of Engineering)</td>
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<td>Materials Engineering Elective†</td>
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<tr>
<td>2nd</td>
<td>Materials Science and Engineering 150 — Introduction to Polymers</td>
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<td>HSSEAS GE Elective</td>
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<td>Materials Engineering Elective†</td>
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<td>Materials Engineering Laboratory Course†</td>
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<tr>
<td>3rd</td>
<td>Materials Science and Engineering 140 — Materials Selection and Engineering Design</td>
<td>4</td>
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<td>HSSEAS GE Elective</td>
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<td>Materials Engineering Laboratory Course†</td>
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</table>

**TOTAL**: 186

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See counselor in 6426 Boelter Hall for details.
B.S. in Materials Engineering
Electronic Materials Option Curriculum

FRESHMAN YEAR

1st Quarter
Chemistry and Biochemistry 20A — Chemical Structure ............................................. 4
English Composition 3 — English Composition, Rhetoric, and Language ..................... 5
Materials Science and Engineering 10 — Freshman Seminar: New Materials .................. 1
Mathematics 31A — Differential and Integral Calculus ................................................. 4

2nd Quarter
Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory ......................................................... 7
Mathematics 31B — Integration and Infinite Series ....................................................... 4
Physics 1A — Mechanics ......................................................................................... 5

3rd Quarter
Computer Science 31 — Introduction to Computer Science I ....................................... 4
Mathematics 32A — Calculus of Several Variables ..................................................... 4
Physics 1B — Oscillations, Waves, Electric and Magnetic Fields ................................ 5
HSSEAS GE Elective* ............................................................................................ 4

SOPHOMORE YEAR

1st Quarter
Materials Science and Engineering 104 — Science of Engineering Materials................. 4
Mathematics 32B — Calculus of Several Variables ..................................................... 4
HSSEAS GE Elective* ............................................................................................ 5

2nd Quarter
Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics) .................. 4
Mathematics 33A — Linear Algebra and Applications .............................................. 4
Physics 1C — Electrodynamics, Optics, and Special Relativity .................................. 5
HSSEAS GE Elective* ............................................................................................ 5

3rd Quarter
Materials Science and Engineering 90L — Physical Measurement in Materials Engineering .................................................................................. 2
Mathematics 33B — Differential Equations .............................................................. 4
Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials ......... 4
HSSEAS Ethics Course ......................................................................................... 4

JUNIOR YEAR

1st Quarter
Electrical Engineering 10 — Circuit Theory I ............................................................. 4
Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Lab ......................................................... 6
Materials Science and Engineering 130 — Phase Relations in Solids ......................... 4

2nd Quarter
Electrical Engineering 101A — Engineering Electromagnetics ................................ 4
Materials Science and Engineering 120 (Physics of Materials) or Electrical Engineering 2 (Physics for Electrical Engineers) ........................................... 4
Materials Science and Engineering 122 — Principles of Electronic Materials Processing .................................................................................. 4
Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Lab ......................................................... 6

3rd Quarter
Electrical Engineering 121B — Principles of Semiconductor Device Design .............. 4
Materials Science and Engineering 121/121L — Materials Science of Semiconductors/Lab ......................................................... 6
Electronic Materials Elective† ............................................................................... 4
Technical Breadth Course* .................................................................................... 4

SENIOR YEAR

1st Quarter
Mechanical and Aerospace Engineering 181A (Complex Analysis and Integral Transforms) or 182A (Mathematics of Engineering) ............................................. 4
Electronic Materials Elective† ............................................................................... 4
HSSEAS GE Elective* ............................................................................................ 5
Technical Breadth Course* .................................................................................... 4

2nd Quarter
Electronic Materials Elective† ............................................................................... 4
Electronic Materials Laboratory Course† .................................................................. 2
HSSEAS GE Elective* ............................................................................................ 5
Technical Breadth Course* .................................................................................... 4

3rd Quarter
Materials Science and Engineering 140 — Materials Selection and Engineering Design .................................................................................. 4
Electronic Materials Electives (2)† ....................................................................... 8
Electronic Materials Laboratory Course† .................................................................. 2

TOTAL .................................................................................................................. 188

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
† See counselor in 6426 Boelter Hall for details.
# B.S. in Mechanical Engineering Curriculum

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<td>Computer Science 31 — Introduction to Computer Science I</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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<td>Physics 4AL — Mechanics Laboratory</td>
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<td>Mathematics 32B — Calculus of Several Variables</td>
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<td>Mechanical and Aerospace Engineering 94 — Introduction to Computer-Aided Design and Drafting</td>
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<td>Physics 1G — Electrodynamics, Optics, and Special Relativity</td>
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<td>Physics 4BL — Electricity and Magnetism Laboratory</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials</td>
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<td>Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics</td>
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<td>Mathematics 33B — Differential Equations</td>
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<td>Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies</td>
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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics</td>
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## JUNIOR YEAR

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<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Mechanical and Aerospace Engineering 105D — Transport Phenomena</td>
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<td>Mechanical and Aerospace Engineering 162A — Introduction to Mechanisms and Mechanical Systems</td>
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<td>Electrical Engineering 110L — Circuit Measurements Laboratory</td>
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<td>Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics)</td>
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<td>Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems</td>
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<td>Mechanical and Aerospace Engineering 156A — Advanced Strength of Materials</td>
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</table>

## TOTAL

185

* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 19 for details).
Index

A
Academic Excellence Workshops, 11
Academic Residence Requirement, 19
Active Materials Laboratory, 99
Admission to the School, 16
As a Freshman, 16
As a Graduate Student, 23
As a Transfer Student, 16
Advanced Placement Examinations, Credit for, 16
Advanced Soil Mechanics Laboratory, 49
Advising, 21
CEED, 11
American Indian Science and Engineering Society, 12
Artificial Intelligence Laboratory, 62
Autonomous Vehicle Systems Instrumentation Laboratory, 99
Bachelor of Science Degrees, Requirements for, 18
Biocybernetics Laboratory, 62
Bioengineering Department, 24
Bachelor of Science Degree, 25, 115
Course Descriptions, 29
Faculty Areas of Thesis Guidance, 28
Graduate Study, 25
Bioinformatics Minor, 58
Biomedical Engineering Laboratory, 62
Biomolecular Engineering Laboratories, 38
Bridge Review for Enhancing Engineering Students (BREES), 11
Building Earthquake Instrumentation Network, 49

C
Career Services, 8
CENS Systems Laboratory, 63
Center for Domain-Specific Computing (CDSC), 112
Center for Excellence in Engineering and Diversity (CEED), 11
Center for Function Accelerated nanomaterial Engineering (FAME), 112
Center for High-Frequency Electronics, 78
Center for Image and Vision Science (CVIS), 63
Center for Information and Computation Security (CICS), 63
Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS), 12, 112
Ceramic Processing Laboratory, 91
CEWS Systems Laboratory, 63
Chemical and Biomolecular Engineering Department, 35
Bachelor of Science Degree, 36, 116–120
Course Descriptions, 40
Facilities, 38
Faculty Areas of Thesis Guidance, 40
Graduate Study, 37

Chemical Kinetics, Catalysis, Reaction Engineering, and Combustion Laboratory, 39
Circuits Laboratories, 78
Civil and Environmental Engineering Department, 45
Bachelor of Science Degree, 45, 121
Course Descriptions, 50
Environmental Engineering minor, 46
Facilities, 49
Faculty Areas of Thesis Guidance, 50
Fields of Study, 48
Graduate Study, 46
Instructional Laboratories, 49
Research Laboratories, 49
Clean Energy Research Center—Los Angeles (CERC-LA), 78
Cognitive Systems Laboratory, 62
Collaborative Design Laboratory, 62
Collective on Vision and Image Sciences, UCLA, 63
Compilers Laboratory, 64
Computational Cardiology Laboratory, 62
Computational Fluid Dynamics Laboratory, 99
Computational Systems Biology Laboratories, 62
Computer Communications Laboratory, 63
Computer Graphics and Vision Laboratories, 63
Computer Networks Laboratories, 63
Computer Science Department, 56
Bachelor of Science Degrees, 57, 122–123
Bioinformatics Course Descriptions, 66
Computer Science Course Descriptions, 66
Computing Resources, 64
Facilities, 62
Faculty Areas of Thesis Guidance, 64
Fields of Study, 60
Graduate Study, 59
Computer Science Theory Laboratories, 63
Computer Systems Architecture Laboratories, 63
Concurrent Systems Laboratory, 63
Continuing Education, UCLA Extension, 7
Correspondence Directory, 6
Counseling, 6
CEED, 11

Dashew Center for International Students and Scholars, 8
Data Mining Laboratory, 64
Degrees
Bachelor of Science (B.S.), 18
Doctor of Philosophy (Ph.D.), 22
Engineer (Engr.), 22
Master of Engineering (M.Engr.), 22
Master of Science (M.S.), 22
Master of Science in Engineering (online), 22
Department Requirements, 20

Departmental Scholar Program, 13
Digital Arithmetic and Reconfigurable Architecture Laboratory, 63
Distributed Simulation Laboratory, 64

E
Electrical Engineering Department, 73
Bachelor of Science Degree, 74, 124–126
Computing Resources, 78
Course Descriptions, 81
Facilities and Programs, 78
Faculty Areas of Thesis Guidance, 80
Graduate Study, 75
Research Laboratories, 78
Electrochemical Engineering and Catalysis Laboratories, 39
Electromagnetics Laboratories, 78
Electron Microscopy Laboratories, 91
Electronic Materials Processing Laboratory, 39
Embedded and Reconfigurable System Design Laboratory, 63
Endowed Chairs, 4
Energy and Propulsion Research Laboratory, 100
Environmental Engineering Laboratories, 49
Environmental Engineering Minor, 46
Ethics Requirement, 19
Experimental Fracture Mechanics Laboratory, 49, 50
Experimental Mechanics Laboratory, 49
Externally Funded Research Centers and Institutes, 112

F
Faculty Laboratories, 79
Fees and Financial Support, 8
Graduate Students, 10
Undergraduate Students, 9
Fees, annual, 9
Fellowships, 10
Financial Aid, 9, 12
Fluid Mechanics Research Laboratory, 100
Freshman orientation course, 11
Fusion Science and Technology Center, 100

G
General Education Requirements, 19
Glass and Ceramics Research Laboratories, 91
Grade Disputes, 14
Grading Policy, 14
Grants, 9

Harassment, 14
Health Center, 8
Health Insurance (UCSHIP), 8
Heat Transfer Laboratories, 100
High-Performance Internet Laboratory, 63
Honorary Societies, 13

H
Honors
Dean's Honors List, 21
Latin Honors, 21
Human/Computer Interface Laboratory, 63
Hydrology Laboratory, 49

Information and Data Management Laboratories, 64
Institutes, Externally Funded, 112
Instructional Computer Facility, 7
International Students, 8
Internet Research Laboratory, 63

Keck Laboratory for Computer Vision, 63
Knowledge-Based Multimedia Medical Distributed Database Systems Laboratory, 64

Library Facilities
Science and Engineering Library (SEL), 7
University Library System, 7
Living Accommodations, 9
Loans, 10

Master of Science in Engineering Online Program, 108
Graduate Study, 108
Materials and Plasma Chemistry Laboratory, 39
Materials Degradation Characterization Laboratory, 100
Materials Science and Engineering Department, 88
Bachelor of Science Degree, 89, 127–128
Course Descriptions, 92
Facilities, 91
Faculty Areas of Thesis Guidance, 91
Fields of Study, 91
Graduate Study, 90
Mechanical and Aerospace Engineering Department, 95
Bachelor of Science Degrees, 96, 114, 129
Course Descriptions, 102
Facilities, 99
Faculty Areas of Thesis Guidance, 100
Fields of Study, 99
Graduate Study, 96
Mechanical Testing Laboratory, 91
Mechanical Vibrations Laboratory, 49
MESA Schools Program, 11
Metallographic Sample Preparation Laboratory, 91

Micro and Nano Manufacturing Laboratory, 100
Microsciences Laboratory, 100
Modeling Animation and Graphics Laboratory (MAGIX), 63
Molecularly Engineered Energy Materials Energy Frontier Research Center, 112
Multidisciplinary Research Facilities, 79
Multifunctional Composites Laboratory, 100
Multimedia Stream System Laboratory, 64
Multimedia Systems Laboratory, 64
Multiscale Thermosciences Laboratory (MTSL), 100

Named Data Networking Project, 113
Nanoelectronics Research Facility, 78
Nano-Materials Laboratory, 91
Nanoparticle Technology and Air Quality Engineering Laboratory, 39
National Society of Black Engineers, 12
Network Research Laboratory, 63
Nondestructive Testing Laboratory, 91
Nondiscrimination, 14

Official publications, 13
Optical Metrology Laboratory, 49
Organic Electronic Materials Processing Laboratory, 91

Parallel Computing Laboratory, 64
Photonics and Optoelectronics Laboratories, 78
Plasma and Beam Assisted Manufacturing Laboratory, 100
Plasma Electronics Facilities, 79
Plasma Propulsion Laboratory, 100
Polymer and Separations Research Laboratory, 40
Precollege Outreach Programs, 11
Prizes and Awards, 13
Process Systems Engineering Laboratory, 40

Reinforced Concrete Laboratory, 49
Research Centers, Externally Funded, 112
Research Intensive Series in Engineering for Underrepresented Populations (RISE-UP), 11

Scholarship Requirement, 19
Scholarships, 9, 12
School Requirements, 19
Schoolwide Programs, Courses, and Faculty, 110
Course Descriptions, 110
Faculty Areas of Thesis Guidance, 110

Graduate Study, 110
Semiconductor and Optical Characterization Laboratory, 91
Services for Students with Disabilities, 8
Shop Services Center, 7
Smart Grid Energy Research Center (SMERC), 113
SMARTS precollege program, 11
SMASH precollege program, 11
Society of Latino Engineers and Scientists, 12
Software Systems Laboratories, 64
Software Systems Laboratory, 64
Soil Mechanics Laboratory, 49, 50
Special Programs, Activities, and Awards, 11
Structural Design and Testing Laboratory, 49
Student Health Center, 8
Student Organizations, 12
Student Societies, 13
Student Study Center, 12
Study List, 20
Subsonic Wind Tunnel, 100
Summer Bridge program, 11

Teaching Assistantships, 10
Technical Breadth Requirement, 19
Theory Laboratory, 63
Thin Film Deposition Laboratory, 91
Thin Films, Interfaces, Composites, Characterization Laboratory, 100

UCSHIP, 8
Unit Requirement, 19
University Requirements, 18

Vision Laboratory, UCLA, 63
VLSI CAD Laboratory, 63

Web Information Systems Laboratory, UCLA, 64
Western Institute of Nanoelectronics (WIN), 113
Wireless Health Institute, 113
Women in Engineering, 13
Work-Study Programs, 10
Writing Requirement, 19

X-Ray Diffraction Laboratory, 91
X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility, 91
## Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2013</th>
<th>Winter 2014</th>
<th>Spring 2014</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 5</td>
<td>October 30</td>
<td>January 29, 2014</td>
</tr>
<tr>
<td>Ursa enrollment appointments begin</td>
<td>June 17</td>
<td>November 12</td>
<td>February 10</td>
</tr>
<tr>
<td>Registration fee payment deadline</td>
<td>September 20</td>
<td>December 20</td>
<td>March 20</td>
</tr>
<tr>
<td>QUARTER BEGINS</td>
<td>September 23</td>
<td>January 2, 2014</td>
<td>March 26</td>
</tr>
<tr>
<td>Instruction begins</td>
<td>September 26</td>
<td>January 6</td>
<td>March 31</td>
</tr>
<tr>
<td>Last day for undergraduates to ADD courses with per-course fee through Ursa</td>
<td>October 18</td>
<td>January 24</td>
<td>April 18</td>
</tr>
<tr>
<td>Last day for undergraduates to DROP nonimpacted courses without a transcript notation (with per-transaction fee through Ursa)</td>
<td>October 25</td>
<td>January 31</td>
<td>April 25</td>
</tr>
<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP) with per-transaction fee through Ursa</td>
<td>November 8</td>
<td>February 14</td>
<td>May 9</td>
</tr>
<tr>
<td>Instruction ends</td>
<td>December 6</td>
<td>March 14</td>
<td>June 6</td>
</tr>
<tr>
<td>Final examinations</td>
<td>December 9-13</td>
<td>March 17-21</td>
<td>June 9-13</td>
</tr>
<tr>
<td>QUARTER ENDS</td>
<td>December 13</td>
<td>March 21</td>
<td>June 13</td>
</tr>
<tr>
<td>HSSEAS Commencement</td>
<td>—</td>
<td>—</td>
<td>June 14</td>
</tr>
<tr>
<td>Academic and administrative holidays</td>
<td>November 11</td>
<td>January 20</td>
<td>March 28</td>
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<td></td>
<td>November 28-29</td>
<td>February 17</td>
<td>May 26</td>
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<td>December 24-25</td>
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<td>December 31-</td>
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<td></td>
<td>January 1</td>
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<td></td>
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<tr>
<td>Winter campus closure</td>
<td>December 23, 26, 27, 30</td>
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</tbody>
</table>

## Admission Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2013</th>
<th>Winter 2014</th>
<th>Spring 2014</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, 2012</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 Diversity, Inclusion, and Admissions (DIA), 1248 Murphy Hall, UCLA, Los Angeles, CA 90024-1419</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
</tr>
<tr>
<td>Last day to file Undergraduate Application for Readmission form at 1113 Murphy Hall (late applicants pay a late fee)</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
</tr>
</tbody>
</table>