ANNOUNCEMENT
OCTOBER 1, 2014

UNIVERSITY OF CALIFORNIA,
LOS ANGELES
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 Applicable to the Disclosure of Information from Student Records, students at UCLA have the right to (1) inspect and review records pertaining to themselves in their capacity as students, except as the right may be waived or qualified under federal and state laws and University policies, (2) have withheld from disclosure, absent their prior written consent for release, personally identifiable information from their student records, except as provided by federal and state laws and University policies, (3) inspect records maintained by UCLA of disclosures of personally identifiable information from their student records, (4) seek correction of their student records through a request to amend the records or, if such request is denied, through a hearing, and (5) file complaints with the U.S. Department of Education regarding alleged violations of the rights accorded them by FERPA.

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

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 attendance, number of course units in which enrolled, and degrees and honors received) of this “public information” released and published may so indicate through MyUCLA (http://my.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 policies may be maintained in a variety of offices, including the Registrar’s Office, Office of the Dean of Students, UCLA Career Center, Graduate Division, 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 student records, together with their campus address and telephone number. Students have the right to inspect their student records in any such office subject to the terms of federal and state laws and University policies. Inspection of student records maintained by the Registrar’s Office is by appointment only and must be arranged three working days in advance. Call (310) 825-1091, 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 Telephone Directory may be inspected in the office of the Information Practices Coordinator, 500 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of the Dean of Students, 1206 Murphy Hall.

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

Cover: Students participate in Engineering Open House activities.
A Message from the Dean

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, robotics, 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, NSF Named Data Networking Project, and the NSF Center for Encrypted Functionalities. 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 28 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
Officers of Administration

Vijay K. Dhir, Ph.D., Professor and Dean of the Henry Samueli School of Engineering and Applied Science
Jane P. Chang, Ph.D., Professor and Associate Dean, Research and Physical Resources
Richard D. Wesel, Ph.D., Professor and Associate Dean, Academic and Student Affairs
Jenn-Ming Yang, Ph.D., Professor and Associate Dean, International Initiatives and Online Education
Mary Okino, Ed.D., Assistant Dean, Chief Financial Officer
M.-C. Frank Chang, Ph.D., Professor and Chair, Electrical Engineering Department
James C. Liao, Ph.D., Professor and Chair, Chemical and Biomolecular Engineering Department
Jens Palsberg, Ph.D., Professor and Chair, Computer Science Department
Jonathan P. Stewart, Ph.D., Professor and Chair, Civil and Environmental Engineering Department
Dwight C. Streit, Ph.D., Professor and Chair, Materials Science and Engineering Department
Tsu-Chin Tsao, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Benjamin M. Wu, D.D.S., Ph.D., Professor and Chair, Bioengineering Department

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 Multifunctional 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 WIN Institute of Neurtonics (WINs) focuses on cutting-edge technology, including nanostructures. 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 (CDSL) 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. The NSF Center for Encrypted Functionalities (CEF) explores program obfuscation which uses new encryption methods to make a computer program, and not just its output, invisible to an outside observer, while preserving how it works—its functionality—thus enhancing cybersecurity. Finally, the California NanoSystems Institute (CNS)—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 24. 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
Volgenau Endowed Chair in Engineering
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, airframe and engine manufacturers, government agencies such as NASA and the military services, and research and development organizations.

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

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

The B.S. program in Aerospace Engineering emphasizes fundamental disciplines and therefore provides a solid base for professional career development in industry and graduate study in aerospace engineering. Graduate education 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, and biotechnology. Chemical and biomolecular engineers 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.

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.
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
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, nondestructive evaluation, and design and optimization of manufacturing processes.

Materials Engineering
Materials engineering is concerned with the structure and properties of materials used in modern technology. Advances in technology are often limited by available materials. Solutions to energy problems depend largely on new materials, such as solar cells or materials for batteries for electric cars. Two programs within materials engineering are available at UCLA:
1. In the materials engineering program, students become acquainted with metals, ceramics, polymers, and composites. Such expertise is highly sought by the aerospace and manufacturing industries. Materials engineers are responsible for the selection and testing of materials for specific applications. Traditional fields of metallurgy and ceramics have been merged in industry, and this program reflects the change.
2. In the electronic materials option of the materials engineering program, students learn the basics of materials engineering with a concentration in electronic materials and processing. The optional program requires additional coursework which includes five to eight electrical engineering courses.

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

Mechanical Engineering
Mechanical engineering is a broad discipline finding application in virtually all industries and manufactured products. The mechanical engineer applies principles of mechanics, dynamics, and energy transfer to the design, analysis, testing, and manufacture of consumer and industrial products. A mechanical engineer usually has specialized knowledge in areas such as design, materials, fluid dynamics, solid 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.
Correspondence Directory

Henry Samueli School of Engineering and Applied Science  
http://www.engineer.ucla.edu

Office of Academic and Student Affairs  
6426 Boelter Hall  
http://www.seasoasa.ucla.edu

Bioengineering Department  
5121 Engineering V  
http://bioeng.ucla.edu

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

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

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

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

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

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

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

Engineering and Science Career Services  
UCLA Career Center  
501 Westwood Plaza, Strathmore Building  
http://career.ucla.edu

Master of Science in Engineering Online Program  
7440 Boelter Hall  
http://msengrol.seas.ucla.edu

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Chemical and Biomolecular Engineering  
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Mechanical Engineering  
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University of California, Los Angeles  
Los Angeles, CA 90095-1361  
http://www.ucla.edu

Undergraduate Admission  
1147 Murphy Hall  
http://www.admission.ucla.edu

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

Financial Aid and Scholarships  
A129J Murphy Hall  
http://www.financialaid.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  
1332 Murphy Hall  
http://www.summer.ucla.edu

University of California  
Office of the President–Admissions  
http://admission.universityofcalifornia.edu
## Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2014</th>
<th>Winter 2015</th>
<th>Spring 2015</th>
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<tbody>
<tr>
<td>First day for continuing students to check MyUCLA at MyUCLA.edu for assigned enrollment appointments</td>
<td>June 2</td>
<td>November 3</td>
<td>January 26</td>
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<tr>
<td>MyUCLA enrollment appointments begin</td>
<td>June 16</td>
<td>November 17</td>
<td>February 9</td>
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<tr>
<td>Registration fee payment deadline</td>
<td>September 20</td>
<td>December 20</td>
<td>March 20</td>
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<tr>
<td>QUARTER BEGINS</td>
<td>September 29</td>
<td>January 5, 2015</td>
<td>March 25</td>
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<tr>
<td>Instruction begins</td>
<td>October 2</td>
<td>January 5</td>
<td>March 30</td>
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<tr>
<td>Last day for undergraduates to ADD courses with per-course fee through MyUCLA</td>
<td>October 24</td>
<td>January 23</td>
<td>April 17</td>
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<tr>
<td>Last day for undergraduates to DROP nonimpacted courses without a transcript notation (with per-transaction fee through MyUCLA)</td>
<td>October 31</td>
<td>January 30</td>
<td>April 24</td>
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<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP) with per-transaction fee through MyUCLA</td>
<td>November 14</td>
<td>February 13</td>
<td>May 8</td>
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<tr>
<td>Instruction ends</td>
<td>December 12</td>
<td>March 13</td>
<td>June 5</td>
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<tr>
<td>Final examinations</td>
<td>December 15–19</td>
<td>March 16–20</td>
<td>June 8–12</td>
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<tr>
<td>QUARTER ENDS</td>
<td>December 19</td>
<td>March 20</td>
<td>June 12</td>
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<tr>
<td>HSSEAS Commencement</td>
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<td>June 13</td>
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<td>Academic and administrative holidays</td>
<td>November 11</td>
<td>January 19</td>
<td>March 27</td>
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<td>November 27–28</td>
<td>February 16</td>
<td>May 25</td>
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<td>December 24–25</td>
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<td>December 31–January 1</td>
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<tr>
<td>Winter campus closure</td>
<td>December 26, 29–30, January 2</td>
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## Admission Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2014</th>
<th>Winter 2015</th>
<th>Spring 2015</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, 2013</td>
<td>—</td>
<td>—</td>
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<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>
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<td>Consult department</td>
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<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>
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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.seas.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 10 million volumes, and over 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 combined Science and Engineering Library (SEL) collections contain more than half a million print volumes; subscriptions to nearly 5,400 print or electronic journals, many with full archival access; a large collection of online technical reports; and over 50,000 e-books. The library provides Web access to online databases covering each discipline. The SEL/Engineering and Mathematical Sciences Collection, 8270 Boelter Hall, focuses on engineering, mathematics, statistics, astronomy, chemistry, physics, and atmospheric and oceanic sciences, and is the location of most librarian and staff offices. The library also provides laptop checkout, group study rooms, a presentation rehearsal studio, a research commons for collaborative projects, and quiet areas for study.

The SEL/Geology-Geophysics Collection, 4697 Geology Building, focuses on earth and space sciences with materials in geochemistry, geology, hydrology, tectonics, water resources, geophysics, and space physics. The William C. Putnam Map Room includes U.S. and international topographic and geologic maps.

The SEL website, located at http://library.ucla.edu/libraries/sel/, provides access to all SEL resources. It also offers information on course reserves, laptop lending, interlibrary loan, document delivery, the SEL blog, and a staff directory. Librarians are available for consultations and to provide course-related instruction on using electronic and print resources including journal article databases, the UCLA Library catalog, Web search engines, research impact metrics, research data management and curation, scholarly communication, copyright, and open access publishing.

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 NAS 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 back-end 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 computationally 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 downtimes.

Students and faculty have access to free retail Microsoft software through the Microsoft Dream Spark Premium program, and MathType software through the HSSEAS download service. Faculty and staff have access to Adobe professional and Microsoft Office (MCCA) software at no charge. 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 UNEX, 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 88th offering in September 2014 and 89th in March 2015. See https://www.uclaextension.edu/tmp/.
The Information Systems program offers over 100 courses annually in applications programming, database management, information systems security, Linux/UNIX, operating systems, systems analysis, and Web technology. The engineering program offers over 200 courses annually, including 10 certificate programs in astronomical engineering, biotechnology engineering, communication systems, construction management, contract management, digital signal processing, government cost estimating and pricing, manufacturing engineering, medical device engineering, project management, recycling and solid waste management, and supply chain 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/eismv.

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

Services include career consulting and counseling, skills assessments, workshops, employer information sessions, and a multimedia collection of career planning and job search resources. Bruinview™ provides 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 therapy. The center has its own pharmacy, optometry, radiology, and laboratory. Visits, core laboratory tests, X-rays, and preventive immunizations are all prepaid for students with the University of California Student Health Insurance Plan (UCSHIP). UCSIHP students are expected to begin all nonemergency medical care at the Ashe Center, after which they may be referred (as medically necessary) to an outside participating network provider. UCSIHP students must obtain a referral from the Ashe Center before receiving nonemergency medical services. Claims are not considered for payment without an Ashe Center referral. For emergency care when the Ashe Center is closed, students may call nurse line telephone triage services at (877) 351-3457 (open 24 hours a day, seven days a week), or obtain treatment at the UCLA Medical Center Emergency Room, the nearest emergency room, or a network urgent-care provider. It is the student’s responsibility to have insurance billed. A student with UCSIHP must have follow-up visits, after emergencies, at the Ashe Center. If care cannot be provided at the Ashe Center, its clinician will give the student a written referral to a network provider.

For specific UCSIHP benefits tier structure and coverage information, see the Ashe Center website and select “Insurance,” send e-mail to shshepb@ashe.ucla.edu, or call (310) 825-4073. 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.

The plan year deductible is waived for services provided at the Ashe Center and for payable emergency room visits, urgent care visits, and network provider office visits. A copayment applies for these services. All fees incurred at the Ashe Center are billed directly to students’ BruinBill accounts. The cost of services received outside the Ashe Center is each student’s financial responsibility. Students who waive UCSIHP 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.

A student with UCSIHP who is dismissed, takes a leave of absence, or withdraws during a term with a less than 100 percent refund continues to be eligible for health services for the remainder of the term.

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 facilities, 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 UCLA’s Disabilities and Computing Program, and processing of California Department of Rehabilitation authorizations. There is no fee for any of these services. All contacts and assistance are handled confidentially. Located at A255 Murphy Hall, voice (310) 825-1501, 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 2014-15 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-
In addition to the fees listed, students should be prepared to pay living expenses for the academic period.

**Living Accommodations**

Housing in Los Angeles, 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, https://housing.ucla.edu/community-housing, 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 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 https://housing.ucla.edu/student-housing. 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 2015-16 academic year is March 2, 2015. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA). International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

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

**Scholarships**

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

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

**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 2013-14, HSSEAS awarded more than 140 undergraduate scholarship awards totaling more than $720,000. 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 Appendix A. Undergraduate scholarship information on all available scholarships, see https://www.studentaid.ucla.edu/. Undergraduate scholarship awards totaling more than $720,000. 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 https://www.studentaid.ucla.edu/

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### Table: 2014-15 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES

<table>
<thead>
<tr>
<th></th>
<th>Undergraduate Students</th>
<th>Academic Master's Students</th>
<th>Academic Doctoral Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resident</td>
<td>Nonresident</td>
<td>Resident</td>
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<tr>
<td>Student Services Fee</td>
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<td>$ 972.00</td>
<td>$ 972.00</td>
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<td>Tuition</td>
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<td>$11,220.00</td>
<td>$11,220.00</td>
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<td>Undergraduate Students Association Fee</td>
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<td>PLEDGE Fee</td>
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<td>Arts Restoring Community Fee</td>
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<td>Graduate Students Association Fee</td>
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<td>Ackerman/Kerckhoff Seismic Fee</td>
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<td>Wooden Center Fee</td>
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<td>Student Programs, Activities, and Resources Complex Fee</td>
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<td>Student Health Insurance Plan (UCSHIP)</td>
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<td>$1,938.30</td>
<td>$3,011.10</td>
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<td>varies, see course listings</td>
<td>varies, see course listings</td>
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<tr>
<td>Nonresident Supplemental Tuition**</td>
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<td>$14,966.94</td>
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<td>Continuing student total mandatory</td>
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<td>New student total mandatory fees</td>
<td>$15,131.94</td>
<td>$15,131.94</td>
<td>$15,662.09</td>
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</tbody>
</table>

*Effective Fall Quarter 2014, the unit-based IEI fee is converted to a campus-based flat fee. This is not a fee increase.

**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.
http://www.seasoasa.ucla.edu/student-opportunities/folder-scholarships-for-undergraduates/scholarships-for-undergraduates.

Grants

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

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, A129J Murphy Hall, or on the web at http://www.financialaid.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 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 supple-mental 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 interterm breaks is possible, depending on the availability of research funds from contracts or grants.

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

Applicants for departmental financial support must be accepted for admission to HSSEAS in order to be considered in the 2014-15 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 Financial Aid and Scholarships, A129J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid (FAFSA).

Continuing graduate students should contact Financial Aid and Scholarships in December 2014 for information on 2015-16 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:

Atlantic Richfield Company (ARCO) Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering
Balu and Mohini Balakrishnan Endowed Fellowship. Supports doctoral study in computer science
William and Mary Beedle Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering
John H. Bent Merit Scholarship. Bioengineering Department; supports graduate students with preference given to candidates interested in development or application of powered surgical instruments
John J. and Clara C. Boelter Fellowship. Supports study in engineering
Broadcom Fellowship. Electrical Engineering Department; supports doctoral students who have passed the preliminary examination and are doing research that explores new possibilities in state-of-the-art 22-nm CMOS technology
Broadcom Foundation First Year Fellowship. Supports first-year doctoral students in electrical engineering
Leon and Alyne Camp Fellowship. Supports graduate study in electrical and/or mechanical engineering, must be U.S. citizen
Deutsch Company Fellowship. Supports engineering research on problems that aid small business in Southern California
Electrical Engineering Graduate Fellowship. Supports master’s or doctoral study in electrical engineering
Venky Harinarayan Fellowship. Supports doctoral study in computer science
IBM Doctoral Fellowship. Supports doctoral study in computer science
Qualcomm Innovation Fellowship. Computer Science Department; supports doctoral study in selected areas of computer science
Intel Fellowship. Mechanical and Aerospace Engineering Department; supports doctoral students
Intel Foundation Fellowship. Supports graduate study in electrical engineering
The Kalosworks.org Fellowship. Supports graduate students in electrical engineering who have a GPA of at least 3.0 and have demonstrated financial need
Les Knessel Scholarship Fund. Materials Science and Engineering Department; supports master’s or doctoral study in ceramic engineering
Guru Krupa Foundation Fellowships in Electrical Engineering. Multiple fellowships to support graduate study with preference for those conducting research in integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from the Indian Institutes of Technology (IIT) or the Indian Institute of Science, Bangalore
T.H. Lin Graduate Fellowship. Civil and Environmental Engineering Department; supports study in the area of structures
Living Rocks Electrical Engineering Fellowship. Supports graduate study with preference for students conducting research in the areas of integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
Living Spring Fellowship. Electrical Engineering Department; supports graduate students with preference for those conducting research in integrated circuits and embedded systems or signals and systems, and who have an undergraduate degree in electrical engineering degrees from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
Microsoft Fellowship. Supports doctoral study in computer science
Mindspreads Technologies Fellowship. Supports graduate study in electrical engineering
National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) Fellowships. Support study in engineering and science to highly qualified individuals from communities where human capital is virtually untapped
Northrop Grumman Fellowships. Support doctoral study in computer science and graduate study in electrical engineering
H.J. Orchard Memorial Fellowship. Supports graduate study in electrical engineering
Qualcomm Innovation Fellowship. Supports doctoral students across a broad range of technical research areas based on Qualcomm core values of innovation, execution, and teamwork
Raytheon Fellowship. Supports graduate study in electrical engineering with preference for U.S. citizens
Rockwell Fellowship. Supports graduate study in electrical engineering
Martin Rubin Scholarship. Supports two undergraduate or graduate students pursuing a degree in civil engineering with an emphasis in structural engineering
Henry Samueli Fellowship. Electrical Engineering Department; supports master’s and doctoral students
Henry Samueli Fellowship. Mechanical and Aerospace Engineering Department; supports master’s and doctoral students
Texaco Scholarship. Civil and Environmental Engineering Department; supports research in environmental engineering
Many other companies in the area also make arrangements for their employees to work part-time and to study at UCLA for advanced degrees in engineering or computer science. In addition, the Graduate Division offers other fellowship packages including the Dissertation Year, 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 participated in SMASH during 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 perhaps 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.

CEED students participate in a professional development workshop.

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 while providing 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 multiferroic systems.

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 Edgenosische 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 the 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 https://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 pursuits 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.uclanssoles.com.

**Women in Engineering**
Women make up about 22 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.

- AAAEA: Arab American Association of Engineers and Architects
- 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
- CalGeo: California Geoprosessionals 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
- PIE: Pilipinos in Engineering
- REC: Renewable Energy Club at UCLA
- —: Robotics Club
- —: Senior Class Campaign
- SFB: Society for Biomaterials at UCLA
- SAE: Society of Automotive Engineers
- SOLES: Society of Latino Engineers and Scientists
- SWE: Society of Women Engineers
- Tau Beta Pi: Engineering honor society
- Theta Tau: Professional engineering fraternity
- Triangle: Social fraternity of engineers, architects, and scientists
- Upsilon Pi Epsilon: International honor society for the computing and information disciplines

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

**Prizes and Awards**
Each year, 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. The Russell R. O'Neill Distinguished Service Award is presented annually to an upper division student in good academic standing who has made outstanding contributions through service to the undergraduate student body, student organizations, 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, application for 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, A255 Murphy Hall, UCLA, Box 951405, Los Angeles, CA 90095-1405, voice (310) 206-27-2004, TTY (310) 206-3349. See http://www.ada.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://policy.ucop.edu/doc/2710531/PACAOS-110) 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 intervention. Individuals who experience what they consider to be sexual harassment are advised to confront the alleged offender immediately and firmly.

Additionally, an individual who believes that she or he has been sexually harassed may contact the Sexual Harassment Coordinator in 2241 Murphy Hall or a Sexual Harassment Information Center counselor for help and
information regarding sexual harassment complaint resolution or grievance procedures at one of the locations listed below as determined by the complainant’s status at the University at the time of the alleged incident:

1. Campus Human Resources/Employee and Labor Relations, Manager, 200 UCLA Wilshire, (310) 794-0860

2. Campus Human Resources/Staff and Faculty Counseling Center, Coordinator, 380 UCLA Wilshire Center, (310) 794-0248

3. Chancellor’s Office, Sexual Harassment Coordinator, 2241 Murphy Hall, (310) 206-3417

4. Counseling and Psychological Services, Director, 221 Wooden Center West, (310) 825-0768

5. David Geffen School of Medicine, Dean’s Office, Special Projects Director, 12-138 Center for the Health Sciences, (310) 794-1958

6. Graduate Division, Office Manager, 1237 Murphy Hall, (310) 206-3269

7. Healthcare Human Resources, Employee Relations Manager, 400 UCLA Wilshire Center, (310) 794-0500

8. Lesbian Gay Bisexual Transgender Campus Resource Center, Director, B36 Student Activities Center, (310) 206-3628

9. Office of the Dean of Students, Assistant Dean of Students, 1206 Murphy Hall, (310) 825-3871

10. Office of Ombuds Services, 105 Strathmore Building, (310) 825-7627; 52-025 Center for the Health Sciences, (310) 206-2427

11. Office of Residential Life, Judicial Affairs Coordinator, 205 Bradley Hall, (310) 825-3401

12. Resnick Neuropsychiatric Hospital, Administration/Human Resources Associate Director, B7-370 Semel Institute, (310) 206-5258

13. School of Dentistry, Assistant Dean, Student Affairs, A0-111 Dentistry, (310) 825-2615

14. Student Legal Services, Director, A239 Murphy Hall, (310) 825-9894

15. UCLA Extension, Human Resources Director, 629 UNEX Building, (310) 825-4287; Student Services Director, 214 UNEX Building, (310) 825-2656

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://ucop.edu/student-affairs/policies/student-life-policies/pacacos.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, 1206 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

3. Office of Fraternity and Sorority Relations, 400 UCLA Wilshire Center, Special Projects Director, 12-138 http://www.greeklife.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.
Admission 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 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 Undergraduate Admission website at http://www.admission.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.admission.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 2014 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 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, Computer Science and Engineering, and Electrical Engineering majors require only one term of chemistry
4. Computer programming: applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors must take a C++ course equivalent to UCLA's Computer Science 31, and applicants to the Chemical Engineering major must take a MATLAB course equivalent to UCLA's Mechanical and Aerospace Engineering M20. Applicants to other majors may take either course, but the MATLAB course is preferred. Students at a school that does not offer MATLAB or C++ should see www.seasosa.ucla.edu/admissions/undergraduate-admissions
5. One year of biology 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
### 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>No application</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, 4, or 5</td>
<td>8 excess units</td>
<td>No application</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>Macroeconomics</td>
<td>3, 4, or 5</td>
<td>4 excess units, Economics 2 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>English</td>
<td>3, 4, or 5</td>
<td>8 units maximum for both tests</td>
<td>No application</td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3, 4, or 5</td>
<td>8 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>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>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</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, 4, or 5</td>
<td>4 excess units, French 3 (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>Requirements</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
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<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 excess units</td>
<td></td>
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<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td></td>
</tr>
<tr>
<td>Japanese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td></td>
</tr>
<tr>
<td>Latin</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td></td>
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<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td></td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td></td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 3 (4 units) plus 4 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td></td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td></td>
</tr>
<tr>
<td>Mathematics</td>
<td>3</td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>(AB Test: Calculus)</td>
<td>4</td>
<td>4 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td></td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units                                                                    Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
<td></td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td>3</td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>(B Test)</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td></td>
</tr>
<tr>
<td>Physics (C Test: Mechanics)</td>
<td>3</td>
<td>4 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may petition for Physics 1A)</td>
<td></td>
</tr>
<tr>
<td>Physics (C Test: Electricity and Magnetism)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td></td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 excess units)</td>
<td></td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td></td>
</tr>
</tbody>
</table>

requirements. Engineering and computer science courses appropriate for each major may be found at http://www.assist.org.

**Lower Division Courses in Other Departments**

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

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

**Requirements for B.S. Degrees**

The Henry Samueli School of Engineering and Applied Science awards B.S. degrees to students who have satisfactorily completed four-year programs in engineering studies.

Students must meet three types of requirements for the Bachelor of Science degree:

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

University Requirements

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

School Requirements

The Henry Samueli School of Engineering and Applied Science has 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.

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).

Writing I

The Writing I requirement must be satisfied by completing English Composition 3 with a grade of C or better (C– or a Passed grade is not acceptable) by the end of the second year of enrollment.

The Writing I requirement may also be satisfied by scoring 4 or 5 on one of the College Board Advanced Placement 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.

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 art, 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 and Chemical Engineering majors. 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/.

Intersegmental General Education Transfer Curriculum

Transfer students from California community colleges have the option to fulfill UCLA lower division GE requirements by completing the Intersegmental General Education Transfer Curriculum (IGETC) prior to transfer. The curriculum consists of a series of subject areas and types of courses which have been agreed on by the University of California and the California community colleges. Although GE or transfer core courses are degree requirements rather than admission requirements, students are advised to fulfill them prior to transfer. The IGETC significantly eases the transfer process, as all UCLA GE requirements are fulfilled when students complete the IGETC courses. Students who select the IGETC must complete it entirely before enrolling at UCLA. Otherwise, they must fulfill the Henry Samueli School of Engineering and Applied Science GE requirements. The school does not accept partial IGETC.

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 Division 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 MyUCLA at http://my.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 MyEngineering (https://my.engineering.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 2014-15 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 3.872 or better) for summa cum laude, the next five percent (GPA of 3.775 or better) for magna cum laude, and the next 10 percent (GPA of 3.631 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 3.872 grade-point average for summa cum laude, a 3.775 for magna cum laude, and a 3.631 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field courses. To be eligible for an award, students should have completed at least 80 upper division units at the University of California.
Graduate Programs

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

Also, a one-year program leading to a Certificate of Specialization is offered in various fields of engineering and applied science. Graduate degree information is updated annually in Program Requirements for UCLA Graduate Degrees at http://grad.ucla.edu/gasas/library/pgmrintro.htm.

Master of Science in Engineering Online Degree

The primary purpose of the Master of Science in Engineering online self-supporting 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://msengr.seas.ucla.edu.

Master of Engineering Degree

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

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

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

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

Concurrent Degree Program

A concurrent degree program between HSSEAS and the Anderson Graduate School of Management allows students to earn two master's degrees simultaneously: the M.B.A. and the M.S. in Computer Science. Contact the Office of Academic and Student Affairs for details.
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
tx: (310) 794-5056
e-mail: bioeng@ee.ucla.edu
http://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 C. 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.
Tzung Hsiai, M.D., Ph.D., in Residence
Bahram Jalali, Ph.D.
Chang-Jin Kim, Ph.D.
Debio Li, Ph.D., in Residence
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering)
Wentai Liu, Ph.D.
Aman Mahajan, M.D., Ph.D., in Residence
Aydogan Ozcan, Ph.D.
Kalyanam Shivkumar, M.D., Ph.D., in Residence
Ren Sun, Ph.D.
Yi Tang, Ph.D.
Michael A. Teitell, M.D., Ph.D.
Cun Yu Wang, D.D.S., Ph.D.
Gerard C.L. Wong, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Yang Yang, Ph.D.

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

Associate Professors
Pei-Yu Chiou, Ph.D.
Chi On Chui, Ph.D.
Dino Di Carlo, Ph.D.
Daniel B. Ennis, Ph.D., in Residence
Daniel T. Kamei, Ph.D.
Andrea M. Kasko, Ph.D.
Jacob J. Schmidt, Ph.D.

Assistant Professor
Stephanie K. Seidllis, Ph.D.

Adjunct Professor
Howard Winet, Ph.D.

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

Adjunct Assistant Professors
Kayvan Niazi, Ph.D.
Zachary Taylor, Ph.D.

Thomas A. Zangle, Ph.D.

Affiliated Faculty

Professors
Marvin Bergsneider, M.D., in Residence (Neurosurgery)
Douglas L. Black, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Alex A.T. Bui, Ph.D. (Radiological Sciences)
Gregory P. Carman, Ph.D. (Mechanical and Aerospace Engineering)
Yong Chen, Ph.D. (Mechanical and Aerospace Engineering)
Samson A. Chow, Ph.D. (Molecular 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)
Alain 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 Koefler, M.D., in Residence (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
Elliot M. Landaw, M.D., Ph.D. (Biostatistics)
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)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Monticello, 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 Pillon, Ph.D. (Mechanical and Aerospace Engineering)
Zhulin 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)
Ricky Taira, Ph.D., in Residence (Radiological Sciences)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
James G. Tidball, Ph.D. (Integrative Biology and Physiology)
Kang Ting, D.M.D., D.M.Sc. (Dentistry)
Hsiyan-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
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
James W. Bisley, Ph.D. (Neurobiology)
Katrina M. Dipple, M.D., Ph.D. (Human Genetics, Pediatrics)
Jeff D. Eldredge, Ph.D. (Mechanical and Aerospace Engineering)
Thomas G. Graeber, Ph.D. (Molecular and Medical Pharmacology)
William S. Klug, Ph.D. (Mechanical and Aerospace Engineering)

Min Lee, Ph.D. (Dentistry)
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)
Ladjan Shams, Ph.D. (Psychology)
Danny Jl Wang, Ph.D., in Residence (Neurology)
Xinshu Grace Xiao, Ph.D. (Integrative Biology and Physiology)

Assistant Professors
Louis S. Bouchard, Ph.D. (Chemistry and Biochemistry)
Christopher Giza, Ph.D., in Residence (Neurosurgery, Surgery)
Nader Pouratian, Ph.D. (Neurosurgery)
Amy C. Rowat, Ph.D. (Integrative Biology and Physiology)
Dan Ruan, Ph.D. (Radiation Oncology)
Michael R. van Dam, Ph.D. (Molecular and Medical Pharmacology)

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 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.

Undergraduate Study

The Bioengineering major is a designated capstone major. Utilizing knowledge from previous courses and new skills learned from the capstone courses, undergraduate students work in teams to apply advanced knowledge of mathematics, science, and engineering principles to address problems at the interface of biology and engineering and to develop innovative bioengineering solutions to meet specific sets of design criteria. Coursework entails construction of student designs, project updates, presentation of projects in written and oral format, and team competition.

Bioengineering B.S.

Capstone Major

Preparation for the Major

Required: Bioengineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Life Sciences 2 (satisfies HSSEAS GE life sciences requirement), 3, 23L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Students must complete the following courses:

1. Bioengineering 100, 110, 120, 165EW (or Engineering 183EW or 185EW), 167L, 176, 180, 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)

2. Two major field elective courses (8 units) from Bioengineering C101, C106, C131, C155, M260 (a petition is required for M260)

3. Five additional major field elective courses (20 units) from Bioengineering C101 (unless taken under item 2), CM102, CM103, C104, C105, C106 (unless taken under item 2), C131 (unless taken under item 2), CM140, CM145, C147, CM150, C155 (unless taken under item 2), C170, C171, CM178, C179, 180L, C183, C185, CM186, CM187, 199 (8 units maximum)

Three of the major field elective courses and the three technical breadth 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 20 or http://www.registrar.ucla.edu/ge/.

Graduate Study

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

The following introductory information is based on the 2014-15 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 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.

For the comprehensive track, at least 11 courses must be from the 200 series, three of which must be Bioengineering 299 courses. Students must also take one 495 course. One 100-series course may be applied toward the total course and unit requirement. No units of 500-series courses may be applied toward the minimum course requirements except for the field of medical imaging informatics where 2 units of course 597A are required.

For the thesis track, at least 10 of the 13 courses must be from the 200 series, three of which must be Bioengineering 299 courses. Students must also take two 598 courses involving work on the thesis and one 495 course.

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.

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 prospects 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 (BIM) 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, Biomatics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.


Bioinformatics 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 Physiological Science 166 and Molecular, 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 Biomatics 220 or 296B.


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

Medical Imaging Informatics Subfield

Medical imaging informatics (MI) 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 lower-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 I: Core Courses on General Concepts.

Group II: Subfield Specific Courses. At least 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, Biomatics 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 neuroscience 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 others’ language and move comfortably among the intellectual domains of the two fields.

**Course Requirements**

**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, Biomatics 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.

**Faculty Areas of Thesis Guidance**

**Professors**

Denise Aberle, M.D. (U. 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*

Ian 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, biomaterialization, vascular calcification, mesenchymal stem cells*

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

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

Robin L. Garrell, 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)  
*Excimer laser, minimally invasive surgery, biological spectroscopy*

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)  
*Molecular mechanics, nanofluidics, and bio-nano research*

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

Tzung Hsiao, M.D. (U. Chicago, 1993), Ph.D. (UCLA, 2001)  
*Cardiovascular mechano-transduction, MEMS and nanosensors, vascular endothelial dynamics, molecular imaging of atherosclerotic lesions, reactive nitrogen species (RNS) and reactive oxygen species (ROS)*

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

**Other electives are approved on a case-by-case basis**
Bioengineering / 31

Chi On Chui, Ph.D. (Stanford, 2004)
Nano-electronic and optoelectronic devices and technology, heterostructure semiconductor devices, monolithic integration of heterogeneous technology, exploratory nanotechnology

Dino Di Carlo, Ph.D. (U.C Berkeley, 2006)
Microfluidics, biomedical microdevices, cellular diagnostics, cell analysis and engineering

Daniel B. Ennis, Ph.D. (Johns Hopkins, 2004)
MRI, cardiovascular pathophysiology, image processing, continuum mechanics, tensor analysis, soft tissue biomechanics

Daniel T. Karnei, Ph.D. (MIT, 2001)
Cellular bioengineering, rational design of molecular therapeutics, systems-level analyses of cellular processes, drug delivery, diagnostics

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

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

Assistant Professor

Stephanie K. Seiditt, Ph.D. (U. Texas Austin, 2010)
Neural tissue engineering, spinal cord injury, gene therapy, hydrogels, cell-material interactions, high-throughput biological techniques, nervous system extracellular matrix, neural stem cells and development

Adjunct Professor

Howard Winet, Ph.D. (UCLA, 1969)
Bone microcirculation: bone wound healing, tissue engineering, ischemic osteonecrosis, biocompatibility of bone implants; exercise and external stimulation modalities: electromagnetic fields, ultrasound, and hyperbaric oxygen

Adjunct Associate Professor

Skin tissue engineering, bone tissue engineering, vascular tissue engineering, wound healing

Adjunct Assistant Professors

Kayvan Niazi, Ph.D. (UCLA, 2000)
Molecular and cellular bioengineering, immunotherapeutics

Zachary Taylor, Ph.D. (UC Santa Barbara, 2010)
Thz imaging, laser-generated shockwaves

Thomas A. Zangle, Ph.D. (Stanford, 2010)
Fluid and mass transport, microfluidics, image processing, novel imaging platforms

Affiliated Faculty

For areas of thesis guidance, see http://www.bioeng.ucla.edu/people/faculty/affiliate-faculty.

Lower Division Courses

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

19. Fiat Lux Freshman Seminars. (1 Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. 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 at least 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses


Mr. Kamei (W)


Mr. Kamei (F)

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

Mr. Grundfest (F)


Mr. Grundfest (W)

C104. Physical Chemistry of Biomacromolecules. (4) Formerly numbered M104.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 30A, Life Sciences 2, 3, 23L. To understand 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 thermodynamics 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, four hours; discussion, one hour; outside study, seven hours. Enforced requi-

Professor Emeritus

Stem cell identification, regenerative medicine, systems biology

Associate Professors

Optoelectronic systems
C106. Topics in Bioelectricity for Bioengineers. (4) (Formerly numbered M106) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4, 23L, Mathematics 33B, Physics 1C, 4AL, 4BL. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrosalts in dielectric media, building on complexity to ultimately address signal propagation in axons and neuronal networks. Topics include Nernst/Plank and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, voltage-gated potassium, sodium channel opening, with focus on factors that can be used to control channel length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different polymerizations techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerizations, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C206. Letter grading.

Mr. Schmidt (F)

C107. Polymer Chemistry for Bioengineers. (4) (Formerly numbered M107) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course C104 or C105. Fundamental concepts of polymer synthesis, including step-growth, chain-growth, 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 polymerizations, 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, extracorporeal devices, tissue engineering systems, and bioartificial organs. Introduction to pharmacokinetic analysis. Letter grading.

Mr. Kamei (Sp)


Mr. Grundfest, Mr. Schmidt (W)

C131. Nanopore Sensing. (4) (Formerly numbered M131) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 120, Life Sciences 2, Physics 1B. 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 implications. Applications of re- spective pulse sensing, theory and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ion conductance through pores and GHK equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain intuition for complex flows. Forces in particle interaction. Stokes and finite-inertia flows. Fluids around particles with and without finite inertia and implications for particle-particle interactions. Secondary flows induced by structures and applications in complex flows. Particle separations by fluid dynamic forces: field-flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics vocabulary and techniques, design and 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 C255. Letter grading.

Mr. Di Carlo (Sp)

165EW. Bioengineering Ethics. (4) Lecture, four hours; discussion, three hours; outside study, five hours. All professions have ethical rules that derive from moral theory. Bioethics is well-established discipline addressing ethical rules derived from moral theory. Bioethics addresses ethical rules dealing with how to do fertilized eggs become people? Should ending of life ever be assisted? At what cost should it be maintained? Unlike physicians, bioengineers do not make these decisions. Case studies in bioethics addresses ethical issues around problems. Products can include biomaterials selection, cell source, delivery methods, FDA approval processes, and biological responses to artificial skin and artificial tissue, carbon and blade tissue, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of bioengineering products. Corequisites: C147. Letter grading.

Mr. Liu (Sp)

C147. Applied Tissue Engineering: Clinical and Industrial Perspective. (4) (Formerly numbered Biomedical Engineering C147) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisite: course CM120, Chemical Engineering 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering with focus on novel materials and biological tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological responses. Focus on materials, such as when do fertilized eggs become people? Should ending of life ever be assisted? At what cost should it be maintained? Unlike physicians, bioengineers do not make these decisions. Case studies in bioethics addresses ethical issues around problems. Products can include biomaterials selection, cell source, delivery methods, FDA approval processes, and biological responses to artificial skin and artificial tissue, carbon and blade tissue, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of bioengineering products. Corequisites: C147. Letter grading.

Mr. Schmidt (Sp)

CM150. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Formerly numbered Biomedical Engineering CM150) (Same as Chemical Engineering CM150 and Mechanical and Aerospace Engineering CM1810) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to micro- machining 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 MEMS device. Concurrently scheduled with course C250A. Letter grading.

Mr. Chiu (F)

CM150L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory (2) (formerly Mechanical Engineering CM150L) (Same as Chemical Engineering CM150L and Mechanical and Aerospace Engineering CM1810L) Lecture, one hour; laboratory, four hours; outside study, one hour. Enforced requisites: 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 MEMS, including microstructures, microsensors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM250L. Letter grading.

Mr. Chiu (F)

CM155. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Enforced requisites: course 110. Introduction to microflows, equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain intuition for complex flows. Forces in particle interaction. Stokes and finite-inertia flows. Fluids around particles with and without finite inertia and implications for particle-particle interactions. Secondary flows induced by structures and applications in complex flows. Particle separations by fluid dynamic forces: field-flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics vocabulary and techniques, design and 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 C255. Letter grading.

Mr. Di Carlo (Sp)

CM160. Membrane Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM160) (Same as Chemical Engineering CM160) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced 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 arrays, regulatory control, genetics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading.

Mr. Gupta (W)

CM145. Molecular Biotechnology for Engineers. (4) (Formerly numbered Biomedical Engineering CM145) (Same as Chemical Engineering 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 arrays, regulatory control, genetics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading.

Mr. Li (W)

CM144. Biomedical Engineering Principles, Case Studies. (4) Lecture, four hours; discussion, three hours; outside study, five hours. All professions have ethical rules that derive from moral theory. Bioethics is well-established discipline addressing ethical rules derived from moral theory. Bioethics addresses ethical rules dealing with how to do fertilized eggs become people? Should ending of life ever be assisted? At what cost should it be maintained? Unlike physicians, bioengineers do not make these decisions. Case studies in bioethics addresses ethical issues around problems. Products can include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological responses to artificial skin and artificial tissue, carbon and blade tissue, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of bioengineering products. Corequisites: C147. Letter grading.

Mr. Liu (Sp)
vices outweigh need to wait for more scientific confirmation? Are there effective alternatives? Engineering students need to be aware of consequences of applying such devices to all living systems. Emphasis on research and writing within engineering environments. Satisfies engineering writing requirement. Letter grading.

**M187. Bioengineering Laboratory. (4) (Formerly numbered 182.) Lecture, two hours; laboratory, six hours; outside study, four hours. Required requisites: Chemistry 20L. Laboratory experiments in fluorescence microscopy, biopsy devices, and cell culture elucidate design of engineered tissue. Introduction to techniques used in laboratories and their underlying physical or chemical principles. Students connect classical engineering techniques to current biomedical engineering research and reinforce experimental design skills. Letter grading.

Mr. Di Carlo, Mr. Wong (Sp)

**C170. Energy-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C170.) Lecture, three hours; outside study, nine hours. Required requisites: Electrical Engineering 172, 175, Life Sciences 3, Physics 17. Corequisite: course C170L. Introduction to the interplay of diagnostic and therapeutic 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)

**C170L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) (Formerly numbered Biomedical Engineering C170L.) Lecture, four hours; outside study, two hours. Corequisite: course C170. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissue/tissue phantoms, making tissue phantoms, determination of optical properties of different tissues, techniques of temperature distribution measurement. Concurrently scheduled with course C270L. Letter grading.

C171. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) (Formerly numbered Biomedical Engineering C171.) Lecture, four hours; outside study, eight hours. Required: course C170. Designed for physical sciences, life sciences, and engineering majors. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties, and fluorescence spectroscopy biologic media. Concurrently scheduled with course C271. Letter grading.

Mr. Grundfest (W)

**C172. Design of Minimally Invasive Surgical Tools. (4) (Formerly numbered Biomedical Engineering M172.) Lecture, three hours; discussion, two hours; outside study, seven hours. Required requisites: Chemistry 30B, Life Sciences 2, 3, 23L, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Some knowledge of anatomy, physiology, and engineering principles used in design and manufacture of selected medical devices is assumed. Concurrently scheduled with course C272. Letter grading.

Mr. Grundfest (Sp)


Mr. Wu (Sp)

**177A. Bioengineering Capstone Design I. (4) Formerly numbered Biomedical Engineering C177A. Lecture, two hours; laboratory, six hours; outside study, four hours. Required requisites: courses 167L, 176. Lectures, seminars, and discussions on aspects of biomedical device and therapeutic drug development. Corequisite: course C177B. Letter grading.

Mr. Wu (Sp)

**177B. Bioengineering Capstone Design II. (4) (Formerly numbered Biomedical Engineering M182.) Lecture, two hours; laboratory, six hours; outside study, four hours. Required: course 177A. Lectures, seminars, and discussions on current problems in medicine and biology. Corequisite: course C177A. Letter grading.

Mr. Wu (Sp)

**CM178. Introduction to Biomaterials. (4) (Formerly numbered Biomedical Engineering C180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Required requisites: Chemistry 20A, 20B, 20L, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and 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 CM278. Letter grading.

Mr. Di Carlo, Mr. Wong (W)

**CM179. Biomaterials-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C181.) Lecture, three hours; outside study, nine hours. Required requisites: course CM179. Corequisite: course 177A. Basic cell/tissue interactions. Cellular response to biomaterials: vascular response, interface, and clotting, biocompatibility, animal models, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C279. Letter grading.

Mr. Wu (Not offered 2014-15)

**180. System Integration in Biologics, Biology, and Medicine I. (4) Lecture, three hours; discussion, one hour; laboratory, four hours; outside study, three weeks. Corequisite: course 180. Hands-on experimentation and clinical applications of selected medical therapeutic devices associated with cardiovascular and pulmonary disorders. Letter grading.

Mr. Dunn, Mr. Wu (W)

**C183. Targeted Drug Delivery and Controlled Drug Release. (4) (Formerly numbered Biomedical Engineering M183.) Lecture, three hours; discussion, two hours; outside study, seven hours. Required requisites: Chemistry 20A, 20B, 20L. New therapies require comprehensive understanding of modern biology, pharmacology, biodynamics, and engineering. Targeted delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and drug pharmacodynamics and clinical pharmacokinetics. Application of engineering principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of therapeutic devices that can provide spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistries of materials and physical presentation of devices and how they contribute to the overall outcome. Concurrently scheduled with course C283. Letter grading.

Ms. Kasko (Sp)

**M184. Introduction to Computational and Systems Biology. (2) (Formerly numbered Biomedical Engineering M184.) (Same as Materials and Systems Biology M184 and Computer Science M184.) Lecture, two hours; outside study, four hours. Required: course from Civil Engineering M20, Computer Science 31, Mechanical and Aerospace Engineering M20, or Program in Computing 10A, and Mathematics 2B or 31B. Survey course designed to introduce students to computational and systems biology research in medicine, and biology, providing motivation, flavor, culture, and cutting-edge contributions in computational biosciences and aiming for more informed basis for focused studies by students with computational and systems biology interests. Presentations by individual UCLA researchers discussing their active computational and systems biology research. P/NP grading.

Mr. Di Stefano (F)

**C185. Introduction to Tissue Engineering. (4) (Formerly numbered Biomedical Engineering C185.) Lecture, three hours; discussion, one hour; outside study, eight hours. Required: course CM102 or CM166. Corequisite: Chemistry 20A, 20B, 20L. Designed for engineers. Corequisite: course 185 applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course C285. Letter grading.

Mr. Wu (W)

**CM186. Computational Systems Biology: Modeling and Simulation of Biological Systems. (4) (Formerly numbered Biomedical Engineering CM186.) (Same as Computational and Systems Biology M186 and Computer Science CM186.) 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, multicomponent, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Emphasis on both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of dynamic simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286. Letter grading.

Mr. Di Stefano (F)

**CM187. Research Communication in Computational and Systems Biology. (2 to 4) (Formerly numbered Biomedical Engineering CM187.) (Same as Computational and Systems Biology M187 and Computer Science CM187.) Lecture. Seven weeks. Required: 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 oral presentations and written progress reports explain how to proceed with search for research results. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading.

Mr. Di Stefano (Sp)

**188. Special Courses in Bioengineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics. Special topics choosing 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. Dunn (W)
Graduate Courses

C201. Engineering Principles for Drug Delivery. (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 colloidal stability. Analysis of linking and visualization of both molecules and the experiment of endocytosis and intracellular trafficking mechanisms. Analysis of diffusion process, coupled with computational and engineering mathematics approaches. Concurrently scheduled with course C202. Mr. Kamei (F)

CM202. Human Physiological Systems for Bioengineering I. (Formerly numbered Biomedical Engineering CM202.) (Same as Physiology Scientific CM204.) Lecture, three hours; laboratory, two hours. Preparation for human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) to systematic basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM102. Letter grading.

Mr. Grundfest (F)


Mr. Grundfest (W)

C204. Physical Chemistry of Biomacromolecules. (Formerly numbered Biomedical Engineering C204.) 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 thermodynamics and phase behavior, polymer networks, and viscoelasticity. Application of engineering principles to problems involving biomacromolecules such as conformational solvation of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C104. Letter grading. Ms. Kasko (F)

C205. Engineering of Bioconjugates. (Formerly numbered Biomedical Engineering C205.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry, one polymer chemistry or engineering. Introduction to synthesis of bioconjugates for 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 variability of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including chemical conjugation linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C105. Letter grading. Mr. Deming (F)

C206. Topics in Bioelectricity for Bioengineers. (Formerly numbered Biomedical Engineering C206.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Chemistry 20B, Life Sciences 2, 3, 4, 23L, Mathematics 33B, Physics 1C, 4AL, 4BL. Coverage in depth of physical processes associated with biological membranes and cell biology. Emphasis on specific topics in electrophysiology. Basic physical principles governing electrostatics in dielectric media, building on complexity to ultimately address action potentials and cellular communication. 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 (F)

C207. Polymer Chemistry for Bioengineers. (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 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 synthesis routes on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C107. Letter grading.

Mr. Deming (W)


Ms. Ahwan (W)

M215. Biochemical Reaction Engineering. (Formerly numbered Biomedical Engineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemical Engineering 211C. Use of key concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biochemical reactions. Concurrently scheduled with course C217. Letter grading.

M217. Biomedical Imaging. (Formerly numbered Biomedical Engineering M217.) (Same as Electrical Engineering M217.) Lecture, three hours; outside study, nine hours. Requisite: Electrical Engineering 114 or 211A. Optical imaging modalities in biomedicine and medical imaging, with emphasis on near-field microscopy and diffraction limited imaging for comparison purposes. Letter grading.

M219. Principles and Applications of Magnetic Resonance Imaging. (Formerly numbered Biomedical Engineering M219.) (Same as Biomedical Engineering M219.) Lecture, three hours; discussion, one hour. Basic principles of magnetic resonance (MR), physics, and image formation. Emphasis on hardware, Bloch equations, analytic expressions, image formation mechanisms, spatial and frequency encodes, and gradient echoes. Fourier transform imaging methods, structure of pulse sequences, and various scanning parameters. Introduction to advanced techniques in rapid imaging, quantitative imaging, and spectroscopy. Letter grading.

220. Introduction to Medical Informatics. (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 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 information system architectures, data and process modeling, information extraction and representations, information integration, information retrieval techniques, research and development, telemedicine. Emphasis on current research endeavors and applications. S/U grading.

Mr. Kangarloo (F)

221. Human Anatomy and Physiology for Medical and Imaging Informatics. (Formerly numbered Biomedical Engineering 221.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understanding and visualization of anatomy and physiology through medical images. Topics relevant to acquisition, representation, and dissemination of anatomical images in the computer age. Topics include brain, chest, cardiovascular, skeletal, musculoskeletal, neural, and soft tissue systems. Introduction to basic imaging physics (magnetic resonance, computed tomography, ultrasound, computed radiography) to provide context for imaging modalities predominantly used to view human anatomy. Geared toward nonphysicians who require more formal understanding of human anatomy/physiology. Letter grading.

222A-223B-223C. Programming Laboratories for Medical and Imaging Informatics I, II, III. (4-4-4) (Formerly numbered Biomedical Engineering 222A-223B-223C.) Lecture, two hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Programming laboratories to support coursework in other medical and imaging informatics core curriculum courses. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used in image processing and medical information system infrastructures. Letter grading. 222A, Requisites: Computer Science 31, 32, Program in Computing 20A, 20B. Course 223A is requisite to 223B, which is requisite to 223C. Integrated with topics presented in course M227 to reinforce concepts presented with practical experience. Projects focus on understanding medical networking issues and implementation of basic protocols for healthcare environment, with emphasis on use of DICOM. Introduction to basic tools and methods of testing within informatics. Requisite: course 222A. Integrated with topics presented in courses 222A, 222B, and 222C to reinforce concepts presented with practical experience. Projects focus on understanding medical imaging and support systems. 223C. Requisite: course 223B. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used in image processing and medical information system infrastructures. Letter grading. 222A, 222B, 222C, 223A, 223B, 223C. Letter grading.
224A. Physics and Informatics of Medical Imaging. (4) (Formerly numbered Biomedical Engineering 224A.) Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to principles of medical imaging and imaging informatics for non-physicists. Overview of core imaging modalities: X-ray, computed tomography (CT), and magnetic resonance imaging (MRI). Topics include signal generation, localization, and quantization. Image representation and analysis techniques such as Markov random fields, spatial data bases, denoising of images, and medical imaging workstations. Design. Provides basic understanding of issues related to basic medical image acquisition and analysis. Current research efforts with focus on clinical applications and new types of information made available through these modalities. Letter grading.

Mr. Morioka (W)

224B. Advances in Imaging Informatics. (4) (Formerly numbered Biomedical Engineering 224B.) Lecture, four hours; outside study, eight hours. Requisites: course 224A. Overview of information retrieval techniques in medical imaging and informatics-based applications. Focus on various advancements in the field. Introduction to core concepts in information retrieval (IR), reviewing seminal papers on evaluating IR systems and their use in medicine (e.g., teaching files, case-based retrieval, etc.). Medical content-based image retrieval (CBIR) as motivating application, with examination of core work in this area. Techniques to realize medical CBIR, including image feature extraction and process, feature representation, classification schemes (via machine learning), image indexing, image querying methods, and visualization of images (e.g., perception, presentation). Discussion of more advanced methods now being pursued such as graph-based CBIR (Mr. Morioka (Sp)).

M225. Bioseparations and Bioprocess Engineering. (4) (Formerly numbered Biomedical Engineering M225.) (Same as Chemical Engineering CM225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: Chemical Engineering 101C. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole blood, plasma, viral vaccines, and 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 M253.) Seminar, four hours; outside study, eight hours. Designed for graduate students. Issues related to medical knowledge representation and its application in healthcare processes. Topics include summary structures for representing knowledge (conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (data mining, statistical classifiers, and hierarchical classification), and basic information retrieval. Review of work in constructing ontologies, with focus on existing implementations of different ontologies. Common medical ontologies, coding schemes, and standardized indices/terminologies (SNOMED, UMLS). Letter grading.

Mr. Tara (Sp)

M227. Medical Information Infrastructures and Internet Technologies. (4) (Formerly numbered Biomedical Engineering M227.) (Same as Information Studies M254.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to medical information infrastructures and implementation infrastructures in medical environment. Exposure to basic concepts related to networking at several levels: low-level (TCP/IP services), medium-level (network protocols), high-level (distributed processing, Web-based services) implementations. Commonly used medical communication protocols (HL7, DICOM) and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless health systems, peer-to-peer topologies, grid computing, and decision support and encryption in networked environments. Letter grading.

Mr. Bui (F)

M228. Medical Decision Making. (4) (Formerly numbered Biomedical Engineering M228.) (Same as Information Studies M258.) Lecture, four hours; discussion, one hour; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine decision processes, need to revisit process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and algorithmic methods for decision-making process. Focus on nuclear medicine data, diagnosis, hypothesis testing, and estimation. Focus on technical advances in medical decision support systems and expert systems, with review of classic and current research. Introduction to common statistical and decision-making software packages to familiarize students with current tools. Letter grading.

Mr. Kangarloo (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 transduction, sensing theory and instrumentation of electrical measurements in electrolytes, nanopore fabrication, ionic conductance through nanoscale gaps in nanopore, 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 C239A. Letter grading.

Mr. Wong (Sp)

C233A. Advancing Bioengineering Innovations I: Unmet Needs. (4) Lecture, three hours; discussion, three hours; outside study, six 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 prototypes for product development, regulatory approaches, or proof-of-concept. 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- and RNA-based diagnostics and drug delivery, gene and tissue engineering. May be taken independently for credit. Concurrently scheduled with course CM140. Letter grading.

Mr. Wong (Sp)

C233B. Advancing Bioengineering Innovations II: Developing and Implementing Medtech Solutions. (4) Lecture, three 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- and RNA-based diagnostics and drug delivery, gene and tissue engineering. May be taken independently for credit. 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, two hours; outside study, seven hours. Requisites: course CM202, Chemistry 20A, 20B, 20L, Life Sciences 1 or 2. Overview of central topics of tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical and biological testing. Case studies include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing considerations, scaled-up production, challenges in design and development of tissue-engineering devices. Concurrently scheduled with course C147. Letter grading.

Mr. Wu (Sp)

M244. Introduction to Biomedical Imaging. (4) (Formerly numbered Biomedical Engineering M244.) (Same as Biomedical Physics M248 and Pharmacology M248.) Lecture, three hours; laboratory, one hour; outside study, seven hours. Exploration of role of biological imaging in medical research and practice, including imaging physics, instrumentation, image processing, and applications of imaging for
range of modalities. Practical experience provided through a series of imaging laboratories. Letter grading.

CM250A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) (Formerly numbered Biomedical Engineering CM250A.) (Same as Electrical Engineering CM280A and Mechanical and Aerospace Engineering CM280A.) 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 this methods can be used to produce variety of MEMS, including microstructures, microsensors, and microactuators. Designers will learn micromachining processes capable of achieving desired MEMS device. Concurrently scheduled with course CM150L. Letter grading. Mr. Chiu (W)

CM250B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Formerly numbered Biomedical Engineering M250B.) (Same as Electrical Engineering CM250B and Mechanical and Aerospace Engineering M280B.) Lecture, one hour; outside study, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: course CM150 or CM250A. Advanced discussion of micro-machining processes used to construct MEMS. Coverage of lithography, photolithography, 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 CM250L.) (Same as Electrical Engineering CM250L and Mechanical and Aerospace Engineering CM280L.) Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM250A, 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 will learn the process of fabricating MEMS device. Concurrently scheduled with course CM150L. Letter grading. Mr. Chiou (F)

CM252, Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Formerly numbered Biomedical Engineering M252.) (Same as Electrical Engineering M252 and Mechanical and Aerospace Engineering M252.) Lecture, one hour; laboratory, four hours; outside study, eight hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. Letter grading. Mr. Wu (Sp)

C255. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, three hours; discussion, seven hours. Enforced requisites: course 110. Introduction to Navier/Stokes equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain intuition into complex flows. Forces on particles in Stokes flow and finite-inertia flows. Flows induced around particles with and without finite inertia and implications for particle-particle interactions. Secondary flows induced by structures and particles in confined flows. Particle separations by fluid dynamic forces: fieldflow fractionation, inertial focusing, structure-induced separation of cells. Applications in intracellular and biological flow and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics vocabulary and techniques, design and model real-world microfluidic devices, and to manipulate microscopic and submicron objects. Letter grading. Mr. Di Carlo (Sp)

257. Engineering Mechanics of Motor Proteins and Cytoskeleton. (4) (Formerly numbered Biomedical Engineering 257.) Lecture, four hours; outside study, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Mathematics 32A, 32B, 33A, 33B, Physics 1A, 1B, 1C. Introduction to physics of motor proteins and cytoskeleton: mass, stiffness and damping of proteins, thermal and mechanical forces, polymer mechanics, structures of cytoskeletal filaments, mechanisms of cytoskeleton polymerization of cytoskeletal filaments, force generation by cytoskeleton and crosslinking, intracellular compositional and actin organization, motor protein structure and operation. Emphasis on engineering perspective. Letter grading.

M260. Neuroengineering. (4) (Formerly numbered Biomedical Engineering M260.) (Same as Electrical Engineering M255 and Neuroscience M260.) Lecture, four hours; laboratory, three hours; outside study, five hours. Enforced requisites: Mathematics 32A, 32B or 6B. Introduction to principles and technologies of neuroengineering. Coverage of neural recording, neural processing (neural signal frequency bands, filtering, spike detection, spike sorting, stimulus artifact removal), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading. Mr. Liu (Sp)


M263. Neuroanatomy: Structure and Function of Nervous System. (4) (Formerly numbered Biomedical Engineering M263.) (Same as Neuroscience M203.) Lecture, three hours; discussion/lab, three hours. Anatomy of central and peripheral nervous system at cellular histological and regional systems level, with emphasis on contemporary experimental approaches to morphological study of nervous system. Discussion of anatomy and neurochemical anatomy of major brain regions. Consideration of representative vertebrate and invertebrate nervous systems. Letter grading.

C270. Energy-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C270.) Lecture, three hours; outside study, nine hours. Enforced requisites: Chemical 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 C170. Letter grading. Mr. Grundfest (F)

C272. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) (Formerly numbered Biomedical Engineering C272L.) Lecture, four hours; outside study, two hours. Corequisite: course C270. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include computer simulations of light propagation in tissue, measuring absorption spectra of tissue, tissue phantoms, making tissue phantoms, measurement differences in different tissue types, techniques of temperature distribution measurements. Concurrently scheduled with course C170. Letter grading.

C271. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) (Formerly numbered Biomedical Engineering C271L.) Lecture, four hours; outside study, eight hours. Corequisite: course C270. Designed for physical scientists, medical physicists, and engineers. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy techniques. Required with course C171. Letter grading. Mr. Grundfest (W)

C272. Design of Minimally Invasive Surgical Tools. (4) (Formerly numbered Biomedical Engineering C272.) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: Chemistry 20B, 20L, Life Sciences 2, 3, 23L, Mathematics 32A. Introduction to design principles and engineering concepts used in design and manufacture of tools for minimally invasive surgery. Coverage of FDA regulatory policy and surgical procedures. Topics include optical devices, endoscopes and laparoscopes, biops, laparoscopic devices, cardiovascular and intraocular instrumentation, and intervention and integration of devices with therapy. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawing and novel devices. Concurrently scheduled with course C172. Letter grading. Mr. Grundfest (Sp)

CM278. Introduction to Biomaterials. (4) (Formerly numbered Biomedical Engineering M278B.) (Same as Materials Science C278 and Engineering Medicine C278.) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L, or Materials Science 104. Engineering materials used in medicine cover a wide range of materials, including metal filaments, active polymerization, motor protein cytoskeletal filaments, for the future of medicine. Letter grading. Concurrently scheduled with course CM178. Letter grading. Mr. Wu (Not offered 2014-15)

C279. Biomaterials-Tissue Interactions. (4) (Formerly numbered Biomedical Engineering C281.) Lecture, three hours; discussion, two hours. Enforced requisites: course CM278. In-depth exploration of host cellular response to biomaterials: vascular response, interface and clotting, biocompatibility, animal cell biology, immune response, cell adhesion and mechanical forces. Concurrently scheduled with course C179. Letter grading. Mr. Wu (Not offered 2014-15)

282. Biomaterial Interfaces. (4) (Formerly numbered Biomedical Engineering C282.) Lecture, four hours; laboratory, eight hours. Enforced requisites: course CM178 or CM278. Function, utility, and biocompatibility of biomaterials depend critically on their surface and interfacial properties. Discussion of the composition of biomaterials and nanoscales, meso-scales, and macroscales, techniques for characterizing structure and properties of biomaterial interfaces. Review methods for evaluating and characterizing biomaterials with prescribed structural and properties in vitro and in vivo. Letter grading. Ms. Maynard (W)

C283. Targeted Drug Delivery and Controlled Drug Release. (4) (Formerly numbered Biomedical Engineering C283.) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. New therapeutics require comprehensive understanding of modern biology, physiology, biotechnology, and engineering. Targeted delivery of genes and drugs and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacokinetics, Application of drug delivery principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and composition of engineered systems, and performance and release. Concurrently scheduled with course C183. Letter grading. Ms. Kasko (Sp)

M284. Functional Neuroimaging: Techniques and Applications. (4) (Formerly numbered Biomedical Engineering M284.) Lecture, four hours; laboratory, four hours. Enforced requisites: Chemistry 20A, 20B, 20L. Functional neuroimaging is important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. Drug pharmacodynamics and clinical pharmacokinetics, Application of drug delivery principles (diffusion, transport, kinetics) to problems in drug formulation and delivery to establish rationale for design and development of novel drug delivery systems that can provide spatial and temporal control of drug release. Introduction to biomaterials with specialized structural and interfacial properties. Exploration of both chemistry of materials and physical presentation of devices and composition of engineered systems, and performance and release. Concurrently scheduled with course C183. Letter grading.
electrophysiologival methods, data acquisition and analysis, development of algorithms, and results obtained thus far in human systems. Strong focus on understanding technologies, how to design activation imaging paradigms, and how to interpret results. Labo-
atory projects in design and implementation of functional MRI experiment. S/U or letter grading.

C285. Introduction to Tissue Engineering. (4) (Formerly numbered Biomedical Engineering C285.) Lect-
ture, three hours; discussion, one hour; outside study, one hour. Requisite: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Focus on design and implementation of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course CM185. Letter grading.

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Formerly numbered Biomedical Engineering CM286.) (Same as Computer Science CM286.) 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 at multiple levels of organiza-
tion. Control system, multicompartamental, pred-
ator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (bio-
chemical 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 sim-
ulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently sched-
uled with course CM186. Letter grading.

Mr. DiStefano (F)

CM287. Research Communication in Computational and Systems Biology. (2 to 4) (Formerly num-
bered Biomedical Engineering CM287.) (Same as Computer Science CM287.) Lecture, four hours; out-
side study, eight hours. Requisite: course CM286. Closely directed, interactive, and real research experi-
ence in active quantitative 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 search for research results. Major 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 Bioen-
gineering. (2 each) (Formerly numbered Biomedical Engineering 295A-295Z.) Seminar, two hours; outside study, four hours. Limited to bioengineering graduate students. Advanced study and analysis of current topics in bioengineering. Discussion of current re-
search and literature in research specialty of faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit. S/U grading.

295A. Biomaterial Research.

295B. Biomaterials and Tissue Engineering Re-
search.

295C. Minimally Invasive and Laser Research.

295D. Hybrid Device Research.

295E. Molecular Cell Bioengineering Research.

295F. Biopolymer Materials and Chemistry.

295G. Biomicrofluidics and Bionanotechnology Re-
search.

295H. Biomimetic System Research.

M296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Formerly num-
bered Biomedical Engineering M296A.) (Same as Computer Science M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requ-
uisite: Electrical Engineering 141 or 142 or Mathe-
matics 115A or Mechanical and Aerospace Engi-
neering 115A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmacological, chemical, and related systems. Control system, multicompartamental, noncompart-
mental, and input/output models, linear and non-
linear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other lim-
ited data environments. Problem solving in PC lab-
atory. Letter grading.

Mr. DiStefano (W)

M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Formerly num-
bered Biomedical Engineering M296B.) (Same as Biomathematics M270C, Computer Science M296D, and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biometrics 220. Estimation meth-
ology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and al-
gorithms for designing optimal experiments for de-
veloping and quantifying models, with special focus on optimal sampling schedule design for kinetic modeling. Exploration of Python programming, for model building and optimal experiment design via applica-
tions in physiology and pharmacology. Letter grading.

Mr. DiStefano (W)

M296C. Advanced Topics and Research in Bio-
medical Systems Modeling and Computing. (4) (Formerly numbered Biomedical Engineering M296C.) (Same as Computer Science M296D and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286. Research techniques and experience on special topics in-
volving models, modeling methods, and model/com-
puting in biological and medical sciences. Review and critique of literature. Research problem search-

Mr. DiStefano (Sp)

M296D. Introduction to Computational Cardi-
ology. (4) (Formerly numbered Biomedical En-
geering 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. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercom-
puters, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.

Mr. Kogan (FSp)

298. Special Studies in Bioengineering. (4) (Formerly numbered Biomedical Engineering 298.) Lec-
ture, four hours; outside study, eight hours. Study of selected topics in bioengineering 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 compa-
nies 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, biophysical cultivation, nano- and micro-
hybrid devices, scaffold engineering, and bioinfor-
matics. S/U grading.

Mr. Wu (F,Sp)

375. Teaching Apprentice Practicum. (4) (Formerly numbered Biomedical Engineering 375.) Seminar, to be arranged. Preparation: apprentice personnel em-
ployment 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.
Chemical and Biomolecular Engineering

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Yi Tang, Ph.D., Vice Chair

Professors
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Panagiotis 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.
Kendall N. Houk, Ph.D. (Saul Winstein Professor of Organic Chemistry)
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering)
Yunfeng Lu, Ph.D.
Vasilios I. Manousiouthakis, Ph.D.
Harold G. Mombouquette, Ph.D.
Stanley J. Osher, Ph.D.
Selim M. Senkan, Ph.D.
Yi Tang, Ph.D., Chancellor’s Professor

Professors Emeriti
Louis J. Ignarro, Ph.D. (Nobel laureate, Jerome J. Beizer Professor Emeritus of Medical Research)
Elidon L. Knuth, Ph.D.
Ken Nobe, Ph.D.
Vincent L. Vilk, Ph.D.
A.R. Frank Wazzan, Ph.D., Dean Emeritus

Associate Professor
Tatiana Segura, Ph.D.

Assistant Professors
Yvonne Y. Chen, Ph.D.
Dante A. Simonetti, Ph.D.

Scope and Objectives
The Department of Chemical and Biomolecular Engineering conducts undergraduate and graduate programs of teaching and research that focus on the areas of biomolecular 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, process 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 industrial technology and for the synthesis of innovative (bi)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 multifaceted 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; they 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; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; 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 Stu-
dent Affairs; two capstone analysis and design courses (Chemical Engineering 108A, 108B); and two elective courses (8 units) from Chemical Engineering 110, C111, C112, 113, C114, C115, C116, C118, C119, C121, C125, C128, C135, C140.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 20 or http://www.registrar.ucla.edu/ge/.

**Biomedical Engineering Option**

**Preparation for the Major**

*Required:* Chemical Engineering 10; Chemistry and Biochemistry 20A, 20B, 20L, 30A, 30AL, 30B; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; 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, 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 20 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; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; 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, 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, C128, 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 20 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; Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20; 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, 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 20 or http://www.registrar.ucla.edu/ge/.
Graduate Study
For information on graduate admission, see Graduate Programs, page 24.
For additional information regarding the B.S., M.S., and Ph.D. in Chemical Engineering, refer to the Chemical and Biomolecular Engineering Department brochure.

The following introductory information is based on the 2014-15 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
The semiconductor manufacturing specialization requires that students have advanced knowledge, assessed in a comprehensive examination, of processing semiconductor devices on the nanoscale.

Course Requirements
The requirements for the M.S. degree are a thesis, nine courses (36 units), and a minimum 3.0 grade-point average in the graduate courses. Chemical Engineering 200, 210, 220, and 222 are required. Two other courses must be taken from regular offerings in the department, while two Chemical Engineering 598 courses involving work on the thesis may also be selected. The remaining two courses may be taken from those offered by the department or any other field in life sciences, physical sciences, mathematics, or engineering. At least 24 units must be in letter-graded 200-level courses.

All M.S. degree candidates are required to enroll in Chemical Engineering 299 during each 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, 103, 105A, 105D, 199.

Semiconductor Manufacturing Specialization
Students are required to complete 10 courses (44 units) with a minimum 3.0 grade-point average overall and in the graduate courses. A minimum of five 200-series courses (20 units) are required, including Chemical Engineering 270 and 270R. Students also are required to take courses 104C, 104CL, Electrical Engineering 122A, and 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. Approved elective courses include Chemical Engineering C214, C218, C219, 223, C240, Electrical Engineering 221A, 221B, 223, 224, Materials Science and Engineering 210, 223.

Students in the specialization who have been undergraduates at or graduates of UCLA and who have already taken some of the required courses may substitute electives for those courses. However, courses taken by students not enrolled in the specialization may not be applied toward the 10-course requirement for the degree. A program of study that encompasses the course requirements must be submitted to the research adviser for approval before the end of the first term in residence and to the departmental Student Affairs Office for approval by Graduate Division before the end of the second term in residence.

Field Experience. Students are required to take Chemical Engineering 270R (directed research course) in the field, working at an industrial semiconductor fabrication facility. The proposed research must be approved by the graduate adviser for semiconductor manufacturing and the industrial sponsor of the research.

Comprehensive Examination Plan
The comprehensive examination plan is only for students in the semiconductor manufacturing specialization.

Students take Chemical Engineering 597A to prepare for the comprehensive examination, which tests for knowledge of the engineering principles of semiconductor manufacturing. In case of failure, the examination may be repeated once within one term with the consent of the graduate adviser. A second failure leads to a recommendation to the Graduate Division for termination of graduate study.

Thesis Plan
The thesis plan is for all M.S. degree students who are not in the semiconductor manufacturing specialization. Students must complete a thesis and should consult the research adviser for details. Students nominate a three-member thesis committee that must meet University requirements and be approved by the Graduate Division.

Chemical Engineering Ph.D.

Major Fields or Subdisciplines
Consult the department.

Course Requirements
All Ph.D. students are required to take six letter graded, 200-level courses (24 units). They can select three chemical engineering core courses from 200, 210, 220, 245, and a graduate engineering mathematics course. Two additional courses must be taken from those offered by the department. The final course can be selected from offerings in life sciences, physical sciences, mathematics, or engineering. 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 minimum 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 Chemical Engineering 299 during each term in residence.

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 Ph.D. students are required to pass the preliminary written examination (PWE) to demonstrate proficiency in at least three of the five core areas as follows.

Students must select the transport phenom- ena core area and either the thermodynamics core area or reaction engineering core...
area or both. If they select only one of thermodynamics or reaction engineering, they must also select either the biomolecular engineering or engineering mathematics core area. The PWE is offered at the end of Winter Quarter of each academic year and is graded by a faculty committee. Students must take the PWE in their first year. If they fail the PWE on the first attempt, they can retake it for a second time the following Spring Quarter. Students who fail both attempts are not allowed to continue in the Ph.D. program.

After completion of the required courses for the degree and passing of the PWE, 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 minimum 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 spectrometers, (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 multiangle laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and (10) phosphoinosfermogor 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 mathematical modeling, to achieve system-wide understanding of the cell.

Protein engineering is being used to generate completely novel compounds that have important pharmaceutical value. Bacteria are being custom-designed to synthesize important therapeutic compounds that have anticancer, cholesterol-lowering, and/or anti-biotic 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 microreactors for catalyst discovery and optimization; several flat premixed and diffusion flame burners and flow reactors to study combustion and other fast reactions; a laser photoionization (LP) time-of-flight (TOF) mass spectrometer for the ultrasensitive, real-time detection of trace pollutants in the gas phase; a gravimetric microbalance to study heterogeneous reactions; and several state-of-the-art supermicro 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 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 rapid thermal processing facility with in-situ vapor phase processing and atomic layer deposition capabilities; advanced plasma processing tools including thin film deposition and etching; and diagnostics including optical emissions spectroscopy, Langmuir probe, and quadrupole mass spectrometry; a surface analytical...
facility including X-ray photoelectron spectroscopy, Auger electron spectroscopy, 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 biomedicalelectronics, and aerospace fields. The laboratory is unique in that it characterizes the reactive species generated in atmospheric plasmas and their chemical interactions with surfaces.

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

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

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

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

Faculty Areas of Thesis Guidance

Professors
Jane P. Chang, Ph.D. (MIT, 1998)
Materials processing, gas-phase and surface reaction, plasma enhanced chemistries, atomic layer deposition, chemical microelectromechanical systems, and computational surface chemistry
Panagiotis D. Christofides, Ph.D. (U. Minnesota, 1996)
Process modeling, dynamics and control, computational and applied mathematics
Yoram Cohen, Ph.D. (U. Delaware, 1981)
Separation processes, graft polymerization, surface nanostructuring, macromolecular dynamics, pollutant transport and exposure assessment
Intelligent systems in process, control operations 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

Kendall N. Houk, Ph.D. (Harvard, 1968)

Computational chemistry, enzyme design, investigation of reaction mechanisms, design of materials and processes


Metabolic engineering, synthetic biology, bioenergy

Yunfeng Lu, Ph.D. (U. New Mexico, 1998)

Semiconductor manufacturing and nanotechnology

Vasilios I. Manousiouthakis, Ph.D. (Rensselaer, 1987)

Biochemical engineering, biosensors, nanotechnology


Computational science, image processing, information science

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)

Biochemical engineering, proteins/polypeptides with unnatural amino acids, synthesis of novel antibiotics/antineumor products

Professors Emeriti

Louis J. Ignarro, Ph.D. (U. Minnesota, 1966)

Regulation and modulation of NO production

Eldon L. Knuth, Ph.D. (Caltech, 1953)

Molecular dynamics, thermodynamics, combustion, applications of air pollution control and combustion efficiency

Ken Nobe, Ph.D. (UCLA, 1956)

Electrochemistry, corrosion, electrochemical kinetics, electrochemical energy conversion, electroabsorption of metals and alloys, electrochemical treatment of toxic wastes, bioelectrochemistry

A.R. Frank Wazzan, Ph.D. (UC Berkeley, 1963)

Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer

Associate Professor

Tatiana Segura, Ph.D. (Northwestern U., 2004)

Gene therapy, tissue engineering, substrate-mediated non-viral DNA delivery

Assistant Professors

Yvonne Y. Chen, Ph.D. (Caltech, 2011)

Synthetic biology, gene-circuit engineering, cell-based therapy, T-cell engineering

Dante A. Simonetti, Ph.D. (U. Wisconsin-Madison, 2008)

Heterogeneous catalysis and adsorption, catalytic reaction engineering and kinetics, design of reactive materials, materials characterization

Lower Division Courses

2. Technology and Environment. (4) Lecture, four hours; discussion, one hour; outside study, seven 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 (chlorofluorocarbon cycles), and global ocean 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 2014-15)

10. Introduction to Chemical and Biomedical Engineering. (1) Lecture, one hour; outside study, two hours. General introduction to field of chemical and biomedical engineering. Description of how chemical and biomedical engineering analysis and design skills are applied for creative solution of current technological problems in production of micro-electronic devices, computer systems, and good environmental impact of manufacturing processes. Application of nanotechnology to chemical sensing, and genetic-level design of recombinant microbes for chemical manufacturing. Letter grading. Mr. Liao (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.

Upper Division Courses

100. Fundamentals of Chemical and Biomedical Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, 20L, Mathematics 32B (may be taken concurrently), Physics 1A. Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programing in MATLAB. Letter grading. Mr. Tang (F)

101A. Transport Phenomena I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33A, 33B. Enforced corequisite: course 109. Introduction to analysis of fluid flow in chemical, biological, and material processes. Fundamentals of momentum transport - Navier-Stokes equation, law of viscosity, mass and momentum conservation in laminar flow, Navier/Stokes equations, and engineering analysis of flow systems. Letter grading. Mr. Senkan (F)

101B. Transport Phenomena II: Heat Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Introduction to analysis of heat transfer in chemical, biological, material, and molecular processes. Fundamentals of thermal engineering - liquid, vapor, heat transfer in gases, liquids, and solids, forced and free convection, radiation, and engineering analysis of heat transfer in process systems. Letter grading. Mr. Monbouquette (W)

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


103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 101A, 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 Biomedical Engineering Laboratory I. (4) Formerly numbered 104AL. Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 100. Enforced corequisite: course 101B. Recommended: course 102B. Not open for credit to students with credit for former course 104AL. Investigation of basic transport phenomena in 10 predetermined experiments, collection of data for statistical analysis and individually written technical reports and group presentations. Design and performance of one original experimental study involving transport, separation, or another aspect of chemical and biomedical engineering. Basic statistics: mean, standard deviation, confidence limits, comparison of two means and of multiple means, simple and multiple variable linear regression, and brief introduction to factorial design of experiments. Oral and poster presentations. Technical writing of sections of technical reports and their contents; writing clearly, concisely, and consistently; importance of word choices and punctuation in multi- and interdisciplinary writing, following required formatting. Letter grading. Mr. Grasel (W,Sp)

104B. Chemical and Biomedical Engineering Laboratory II. (4) Lecture, four hours; laboratory, eight hours; outside study, four hours; other, two hours. Enforced 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 involves theory, experimental procedures, scaleup and process design, and error analysis. Letter grading.

Mr. Grasel, Mr. Simonetti (F,Sp)

104C. Semiconductor Processing. (4) Lecture, four hours; outside study, five hours. Enforced requisite: course 101C. Enforced 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 (Not offered 2014-15)

104CL. Semiconductor Processing Laboratory. (4) Laboratory, four hours; outside study, five hours. Enforced requisite: course 101C. Enforced corequisite: course 104C. Series of experiments that emphasize basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, metallization, and statistical design of experiments and error analysis. Letter grading. Mr. Hicks (Not offered 2014-15)

104D. Molecular Biotechnology Lecture: From Gene to Product. (2) Lecture, two hours; outside study, four hours. Enforced requisites: courses 101C, 125. Enforced corequisite: course 104DL. Integration of molecular and engineering techniques in

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104DL. Molecular Biotechnology Laboratory: From Gene to Product. (4) Laboratory; eight hours; outside study, four hours. Enforced requisites: courses 101A, 101C, 102B. Fundamentals of chemical genetics and catalysis. Introduction to screening of libraries of organisms and applications to the understanding of cellular metabolism. (Not offered 2014-15)

104DL. Molecular Biotechnology Laboratory: From Gene to Product. (4) Laboratory; eight hours; outside study, four hours. Enforced requisites: courses 101A, 101C, 102B. Fundamentals of chemical genetics and catalysis. Introduction to screening of libraries of organisms and applications to the understanding of cellular metabolism. (Not offered 2014-15)

105. Biological Systems Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 104A, 106 (or C115). Integration of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purpose of designing chemical processes and evaluating alternatives. Letter grading. (W)

106. Chemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 100, 101C, 102B. Fundamentals of chemical kinetics and catalysis. Introduction to reaction kinetics and applications of chemical kinetic techniques to the control of complex chemical systems. Letter grading. 

107. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 104A, 106 (or C115). Principles of dynamics modeling and start-up behavior of chemical engineering processes. Chemical process control elements. Design and applications of chemical process computer control. Letter grading. 

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 104A, 106 (or C115). Chemical engineering economics fundamentals. Introduction to design and economic analysis of chemical processes. Letter grading. 

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 104A, 106 (or C115). Chemical and biomedical engineering examples used thoroughly to illustrate application of these methods. Use of MATLAB as platform to write programs based on numerical methods to solve various problems arising in chemical engineering. Letter grading. 


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

112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 331. Description of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer processing diffusion. Diffusion in polymeric systems. Polymers in biomaterial applications and in microelectronics. Concurrently scheduled with course C212. Letter grading. 

113. Air Pollution Engineering. (4) Lecture, four hours; discussion, one hour; outside study, six hours. Enforced requisites: courses 101C, 102B. Inegrated approach to air pollution, including concentrations of atmospheric pollutants, air pollution standards, control, pollution abatement, and relationship of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading. (Not offered 2014-15)

114. Electrochemical Processes and Corrosion. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes and metallic corrosion. Primary emphasis on fundamental approach to analysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal, and semiconductor surface finishing, passivity, electrodereposition, electrosheet deposition, batteries and fuel cells, electrochemistry and bioelectrochemical processes. May be concurrently scheduled with course C214. Letter grading. (Not offered 2014-15)

115. Biochemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101C. Use of previously learned biochemical, chemical 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 C224. Letter grading. 

116. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisites: course 101A, 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 applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading. 


119. Bioseparations and Bioprocess Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: course 101A, 101C, 103. Fundamentals of membrane science and technology, with an emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective 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. 

120. 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, with an emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective 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. 

121. 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 vitro 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, and DNA and siRNA delivery as therapeutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224. Letter grading. 

122. Biosignals and Bioprocess Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced 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. 

123. 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 microorganisms as a tool to comprehend and design metabolic pathways of common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts require profound understanding of network design and regulations and are aided by tools in bioinformatics, systems biology, and molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM227. Letter grading. 

124. Hydrogen. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: Chemistry 20A. Electronic, physical, and chemical properties of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and thermochemical cycles. Description in depth of several uses of hydrogen, including hydrocarbon combustion and hydrogen fuel cells. Concurrently scheduled with course C228. Letter grading. 

125. Advanced Process Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 107. Introduction to advanced process control strategies. Manoussisihakis (Sp)
design of nonlinear and robust controllers for various classes of systems, with applications to gas cleaning, 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)


(Not offered 2014-15)

CM145. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: 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, genomics 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.

194. Research Group Seminars: Chemical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation (2 to 8) hours. Requisite: graduate students who are members. May be repeated once for credit with topic or instructor change. Letter grading.

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

Graduate Courses

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

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 200 or Chemistry C223A or Physics 215A. Modern statistical mechanics for chemical and physical systems. Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading. (Not offered 2014-15)


Mr. Hicks (F)

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; outside study, seven hours. Requisites: courses 102A, 102B (or Materials Science 130). Fundamentals of cryogenics and cryogenic engineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelo- pe needed for operation of cryogenic systems: low-temperature behavior of matter, optimization of cryosystems and other specific 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 360. 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. Enforced requisite: courses 102A, 102B (or Materials Science 130). Fundamentals of electrochemistry and engineering applications to electrochemical systems and their resistance to corrosion. Primary emphasis on fundamental ap- proach to analysis of electrochemical and corrosion processes. Specific topics include corrosion of metals and semiconductors, electrochemical metal and semiconductor surface finishing, passivity, electro- deposition, electroselective deposition, batteries and fuel cells, electroynthesis and bioelectrochemical processes. May be concurrently scheduled with course C114. Letter grading. (Not offered 2014-15)

CM215. Biochemical Reaction Engineering. (4) (Same as Bioengineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced 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. Enforced requisite: course C102A. Introduction to surfaces and interfaces of engineering materials, particularly catalytic surface and thin films for solid-state electronic devices. Topics include classification of crystals, structure and composition of crystals and their surfaces and interfaces. Examination of engineering applica- tions, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concur- rently scheduled with course C116. Letter grading. Ms. Chang (Sp)

217. Electrochemical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course C114. Transport phenomena in electrochemical sys- tems; relationships between molecular transport, convection, and electrode kinetics, along with appli- cations to industrial electrochemistry, fuel cell design, and modern battery technology. Letter grading. Mr. Cohen (F)

(Not offered 2014-15)

C218. Multimedia Environmental Assessment. (4) Lecture, four hours; discussion, one hour; prepara- tion, two hours; outside study, five hours. Recom- mended requisites: courses 101C, 102B. Pollutant sources, emission of source releases, minimi- zation, transport and fate of chemical pollutants in environment, intermedia transfers of pollutants, multi- media modeling of chemical contaminant in environ- ment, exposure assessment and fundamentals of risk assessment, risk reduction strategies. Concurrently scheduled with course C118. Letter grading. Mr. Cohen (F)


Manousiosthakis (Not offered 2014-15)

220. Advanced Mass Transfer. (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Advanced treatment of mass transfer, with applica- tions to industrial separation processes, gas cleaning, pulmonary ventilation, and network problems. Letter grading.

Mr. Cohen (Not offered 2014-15)

C221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, with emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/mor- phology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes and models of mem- branate transport (flux and selectivity). Examples pro- vided from various fields/applications, including bio- technology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C121. Letter grading. Ms. Cohen (Not offered 2014-15)


223. Design for Environment. (4) Lecture, four hours; outside study, eight hours. Limited to graduate chemical engineering, materials science and engi- neering, or Master of Engineering program students. Design of products for meeting environmental objec- tives, lifecycle inventories, lifecycle impact assessment; design for energy efficiency; design for waste minimization, computer-aided design tools, mate- rials selection methods. Letter grading.

C234. Physical 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 vitro cell culture, and drug delivery. Biological principles of cellular microenviron- ment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factors, dense DNA coating, cell adhe- sion and heterogeneity, and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently sched- uled with course C124. Letter grading. Ms. Segura (Not offered 2014-15)
CM225. Bioseparations and Bioprocess Engi-
neering. (5) Lecture, engineering lab, four hours; discus-
ture, discussion, one hour; outside study, seven hours. Enforced corequisite: course 101C. Separation strategies, unit operations, and economic factors unique to processes for isolating and purifying materials like whole cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently scheduled with course C212. Letter grading.
CM227. Synthetic Biology for Biofuels. (4) Con-
sumed as Chemistry CM227.) Lecture, four hours; discus-
sion, one hour; outside study, seven hours. Requi-
sites: Chemistry 153A, Life Sciences 3, 23L. Engi-
neering microbial complex processes, which is a common goal of metabolic engineering and synthetic biology. Production of advanced biofuels involves de-
signing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biotechnology, protein structure, and biological regula-
tions and are aided by tools in bioinformatics, sys-
tem biology, and molecular biology. Fundamentals of metabolic biochemistry, protein structure and function, and bioinformatics. Use of synthetic gen-
coding for metabolic networks to design microorgan-
isms for energy applications. Concurrently scheduled with course CM127. S/U or letter grading. (Not offered 2014-15)

C228. Hydrogen. (4) Lecture, four hours; out-
side study, eight hours. Enforced requisite: Chemistry 20A. Electronic, physical, and chemical properties of hydrogen. Various methods of production, including production through methane steam reforming, elec-
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Civil and Environmental Engineering

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Jonathan P. Stewart, Ph.D., Chair
Scott J. Brandenberg, Ph.D., Vice Chair
Steven A. Margulis, Ph.D., Vice Chair

Professors
Eric M.V. Hoek, Ph.D.
Jennifer A. Jay, 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. Stolzenbach, Ph.D.
Ertugrul Taciroglu, Ph.D.
Miaden 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 F. Felton, Ph.D.
Michael E. Fourney, 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. Selina, Ph.D.

Associate Professors
Scott J. Brandenberg, Ph.D.
Mekonnen Gebremichael, Ph.D.
Jian Zhang, Ph.D.

Assistant Professors
Mathieu Bauchy, Ph.D.
Henry V. Burton, Ph.D.
Shaiy 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.
Michael J. McGuire, Ph.D.
George Mylonakis, Ph.D.
Thomas Sabil, Ph.D.
Ne-Zheng Sun, Ph.D.

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

Scope and Objectives

The Department of Civil and Environmental Engineering programs at UCLA include civil engineering materials, earthquake engineering, environmental engineering, geotechnical engineering, hydrology 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 more 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, M20 (or Computer Science 31); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL; one natural science course selected from Civil and Environmental Engineering 58SL, Earth, Planetary, and Space Sciences 3, 15, 16, 17, 20; Environmental 12; Life Sciences 1, 2; Microbiology, Immunology, and Molecular Genetics 5, 6, or Neuroscience 10.

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 one capstone design course from Civil and Environmental Engineering 123, 144, 147, 152, 157B, or 157C, as well as 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 a laboratory course from the list of additional elective options:

Environmental Engineering: Required: Civil and Environmental Engineering 155 and one capstone design course from 157B or 157C; recommended courses: 154, 163, 164, M165, M166; laboratory courses: 156A, 156B.

Geotechnical Engineering: Required: One capstone design course (Civil and Environmental Engineering 121); recommended courses: C104, 123, 125, C182, Earth, Planetary, and Space Sciences 139; laboratory course: Civil and Environmental Engineering 128L.

Hydrology and Water Resources Engineering: Required: One capstone design course (Civil and Environmental Engineering 151); recommended courses: 152, 157A; laboratory course: 157L.

Structural Engineering and Mechanics: Required: Civil and Environmental Engineering 135B, one lecture course from 130, M135C, 137, 141, or 142, and one capstone design course from 141 or 143; recommended courses: C104, 121, 125, 130, 137, 141, 142, 143, 144, 147, C182; laboratory courses: 130L, 135L, 137L, 140L, 142L.

Additional Elective Options: Atmospheric and Oceanic Sciences 141, Civil and Environmental Engineering 180, 181, Earth, Planetary, and Space Sciences 100, 101, Environment 157, Mechanical and Aerospace Engineering 166C, M168; laboratory course: Civil and Environmental Engineering 129L.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 20 or http://www.registrar.ucla.edu/ge/.

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 154, 155, 156A, M165, M166; Chemical Engineering C118, Environment 159, 166; 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 24.

The following introductory information is based on the 2014-15 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, M116L, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 102, 103, 105A, 105D, 199.

The M.S. degree offers 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 and Water Resources Engineering

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


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.


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.
Structural Mechanics

Required Preparatory Courses. Civil and Environmental Engineering 130, 135A, 135B. Required Graduate Courses. Civil and Environmental Engineering 232, 235A, 235B, 236, M237A.


Comprehensive Examination Plan

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

Thesis Plan

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

Civil Engineering Ph.D.

Major Fields or Subdisciplines

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 resource 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 tools, as well as design recommendations. Reliability-based design and performance assessment methodologies are also an important field of study.

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

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

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

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

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 two campus buildings to measure the response of actual buildings during earthquakes. When combined with over 50 instruments placed in Century City high-rises and other nearby buildings, this network, which is maintained by the U.S. Geological Survey (USGS) and the California Geological Survey’s Strong Instrumentation Motion Program, represents one of the most detailed building instrumentation networks 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 servohydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced by two cranes. The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings. Associated with the laboratory is an electro-hydraulic universal testing machine with force capacity of 100 tons. The machine is used mainly to apply tensile and compressive loads to specimens so that the properties of the materials from which the specimens are made can be determined. It can also be used in fatigue-testing of small components.

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

Faculty Areas of Thesis Guidance

Professors
Eric M.Y. Hoek, Ph.D. (Yale, 2001)
Physical and chemical environmental processes, colloidal and interfacial phenomena, environmental membrane separations, bio-adhesion and bio-fouling
Jennifer A. Jay, Ph.D. (MIT, 1990)
Aquatic chemistry, environmental microbiology
Damage 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 Taciroglu, Ph.D. (U. Illinois Urbana-Champaign, 1998)
Computational structural and solid mechanics and constitutive modeling of materials
Mladen Vucetic, Ph.D. (Pennsylvania, 1986)
Geotechnical engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties
John W. Wallace, Ph.D. (UC Berkeley, 1989)
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

Assistant Professors
Stanley B. Dong, Ph.D. (UC Berkeley, 1962)
Structural mechanics, structural dynamics, finite element methods, numerical methods and mechanics of composite materials
Lewis P. Felton, Ph.D. (Carnegie Institute of Technology, 1964)
Structural analysis, structural mechanics, automated optimal structural design, including reliability-based design
Michael E. Fournier, 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
Poul V. Lade, Ph.D. (UC Berkeley, 1972)
Soil mechanics, stress-strain and strength characteristics of soils, deformation and stability analyses of foundation engineering problems
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
Moshe F. Rubinstein, Ph.D. (UCLA, 1961)
Systems analysis and design, problem-solving and decision-making models
Lucien A. Schmitt, Jr., M.S. (MIT, 1950)
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components
Lawrence G. Selna, Ph.D. (UC Berkeley, 1967)
Reinforced concrete, earthquake engineering

Adjunct Associate Professors
Scott J. Brandenberg, Ph.D. (UC Davis, 2005)
Geotechnical earthquake engineering, soil-structure interaction, liquefaction, data acquisition and processing, numerical analysis
Mekonnen Gebremichael, Ph.D. (U. Iowa, 2004)
Remote sensing of hydrology, watershed hydrologic modeling, hydrometeorology, stochastic processes and scaling
Jian Zhang, Ph.D. (UC Berkeley, 2002)
Earthquake engineering, structural dynamics and mechanics, seismic protective devices and strategies, soil-structure interaction, and bridge engineering

Adjunct Professors
Lawrence G. Selna, Ph.D. (UC Berkeley, 1967)
Control of trace organs in water treatment including activated carbon

Adjunct Associate Professors
Robert E. Kayen, Ph.D. (UC Berkeley, 1993)
Geometrics and terrestrial laser-topographic modeling, geotechnical earthquake engineering, engineering geology, stress wave propagation, foundation engineering

Adjunct Professors
Donald R. Kendall, Ph.D. (UCLA, 1989)
Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes
Issam Najm, Ph.D. (U. Illinois Urbana-Champaign, 1999)
Water chemistry; physical and chemical processes in drinking water treatment

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

Lower Division Courses

1. Civil Engineering and Infrastructure. (2) Lecture, two hours; outside study, four hours. Examples of infrastructure, its importance, and manner by which it is designed and constructed. Role of civil engineers in infrastructure development and preservation, P/NP grading. Mr. Stewart (F), Mr. Chen, Mr. Margulis (W)

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, illuminating many paths of discovery at UCLA. P/NP grading.

M20. Introduction to Computer Programming with MATLAB. (4) Same as Mechanical and Aerospace Engineering M20. Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: Mathematics 33A. Fundamentals of computer programming taught in context of MATLAB computing environment. Basic data types and control structures. Input/output. Functions. Data visualization. MATLAB-
Upper Division Courses

101. Statics and Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: course 31B, Mathematics 33B. This course, or an equivalent course, is required for assigned design problems. Soil classification, grain size distribution, Analysis of stress and strain, phenomenological material behavior, extension, bending, and transverse shear stresses in beams, deflection of beams, torsion of beams, warping, column instability and failure. Letter grading.

Mr. vagi, Mr. Wallare (F, W, Sp)

129L Engineering Geomatics. (4) Formerly numbered 129L) Lecture, two hours; recitation, two hours; laboratory, four hours. Requisites: course 135A. Lec-
137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 135B, Basic structural dynamics course for civil engineering students. Elastic free, forced vibration, and earthquake response spectra for single- and multidegree of freedom systems. Axial, bending, and torsional vibration of beams. Letter grading. Mr. Ju (F)

137L. Structural Dynamics Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours, Requisite: course 135B. Calibration of instrumentation for dynamic measurements. Determination of natural frequencies and damping factors from free vibrations. Determination of natural frequencies and damping factors from forced vibrations. Dynamic similarity. Letter grading. Mr. Wallace (Not offered 2014-15)

140L. Structural Components and Systems Testing Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 142. Comparison of experimental results with analytical results and code requirements to assess accuracies and limitations of calculation procedures used in design in natural and design. Tests include quasi-static tests of structural elements (beams, columns) and systems (slab-column, beam-column) and dynamic tests of simple building systems. Quasi-static tests of elements to compare system stiffness, strength, and deformation capacity, whereas dynamic tests focus on assessment of periods, modes, shapes, and damping. Development of communication skills through preparation of laboratory reports and oral presentations. Letter grading. Mr. Wallace (Sp)


143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Equivalent loads and allowable flexure stresses in determinate and indeterminate systems. Flexural and shear strength design, including secondary effects in indeterminate systems. Design of indeterminate post-tensioned systems using both hand calculations and commercially available computer program. Discussion of external post-tensioning, one- and two-way slab systems. 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 performance of complete building structural systems. International Building Code (IBC) and ASCE 7 dead, live, wind, and earthquake loads. Design of re-inforced concrete and structural steel buildings. Consideration of design and performance for earthquake assessment of buildings. Letter grading. Mr. Wallace (Sp)

147. Design and Construction of Tall Buildings. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course M20, Mechanical and Aerospace Engineering 103. Study of hydrologic cycle and relevant atmospheric processes, water and energy balance, radiation, precipitation formation, infiltration, evaporation, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading. Mr. Sabol, Mr. Wallace (W)

150. Introduction to Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course M20, Mechanical and Aerospace Engineering 103. Study of hydrologic cycle and relevant atmospheric processes, water and energy balance, radiation, precipitation formation, infiltration, evaporation, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading. Mr. Wallace (Sp)

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 150, Mechanical and Aerospace Engineering 103. Recommended: 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. Marioulis (W)

152. Hydraulic and Hydrologic Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 150, 151. Analysis and design of hydraulic and hydrologic systems, including stormwater management systems, potable and recycled water distribution systems, wastewater collection systems, and constructed wetlands. Emphasis on practical design components, including reading/interpreting professional drawings and documents, environmental impact reports, permitting, agency coordination, and engineering ethics. Project-based course includes analysis of alternative design options, use of engineering economics, and preparation of written engineering reports. Letter grading. Mr. Kendall (Sp)

153. Introduction to Environmental Engineering Science. (4) Lecture, four hours; discussion, two hours; outside study, seven hours. Recommended requisite: Mechanical and Aerospace Engineering 103. Water, air, and soil pollution; sources and runoff processes for removal of contaminants. Water quality, water and wastewater treatment, waste disposal, air pollution, global environmental problems. Field trip. Letter grading. Mr. Stolzenbach (F)

154. Chemical Fate and Transport in Aquatic Environ-ments. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended 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.

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

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

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Laboratory, six hours; discussion, two hours; outside study, four hours. Requisite: Chemistry 20A, 20B. Basic laboratory techniques and analysis of typical natural waters and wastewaters for inorganic and organic constituents. Selected experiments include analysis of solids, nitrogen species, oxygen demand, and chlorine residual, that are used in unit operation experiments that include re-actor dynamics, aeration, gas stripping, coagulation/flocculation, and membrane separation. Letter grading. Mr. Stenstrom (W)

157A. Hydrologic Modeling. (4) Lecture, two hours; discussion, two hours; outside study, six hours. Enforced requisite: course 150 or 151. Introduction to hydrologic modeling. Topics include hydrologic processes that shape the earth surface, rainfall-runoff modeling, and groundwater flow and contaminant transport modeling, with focus on use of industry and/or research standard models with locally relevant applications. Letter grading. Mr. Yeh (F)

157B. Design of Water Treatment Plants. (4) Lecture, two hours; discussion, two hours; laboratory, four hours; outside study, four hours. Requisite: course 155. Water quality standards and regulations, overview of water treatment plants, design of unit operations, predesign of water treatment plants, hydraulics, process control, and optimization. Letter grading. Mr. Stenstrom (W)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Requisite: course 155. Process design of wastewater treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and economics. Letter grading. Mr. Stenstrom (Not offered 2014-15)

157L. Hydrologic Analysis. (4) Lecture, two hours; laboratory, four hours; outside study, four 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 rainfall-runoff models and parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Letter grading. Mr. Stenstrom (Not offered 2014-15)

157M. Hydrology of Mountain Watersheds. (4) Lecture, one hour; fieldwork, four hours; laboratory, three hours; outside study, four hours; one field trip. Requisite: course 150 or 157L. Advanced field- and laboratory-based course with focus on study of hydroligic and geochemical processes in snow-domi- nated and mountainous regions. Students measure and quantify snowpack properties, snowmelt, dis- charges, evaporation, and infiltration processes; and parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Letter grading. Mr. Stenstrom (Not offered 2014-15)
M165. Environmental Nanotechnology: Implications and Applications. (4) Same as Environmental Engineering 103, same as Geoenvironmental Engineering 103. Lecture, four hours; outside study, six hours. Recommended prerequisite: Engineering M101. Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) transport and reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Ms. Mahendra (Sp)

M166. Environmental Microbiology. (4) Same as Environmental Health Sciences M166. Lecture, four hours; discussion, two hours; outside study, six hours. Recommended prerequisite: course 153. Microbial cell and its metabolic capabilities, microbial genomics of nanotechnology to environmental systems as concept, performance evaluation; Intelligent Transportation Systems technology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Ms. Sant (W)

M182. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/seniors. General characteristics of transportation systems, including highways, rail, transit and water. Water capacity considerations including time-space diagrams and queueing. Components of transportation system design, including horizontal and vertical alignment, cross sections, earthwork, drainage, and pavements. Letter grading. Mr. Brandenberg (Sp)

181. Traffic Engineering Systems: Operations and Control. (4) Lecture, four hours; fieldwork/laboratory, two hours; outside study, six hours. Designed for juniors/seniors. General characteristics of transportation systems, including highways, rail, transit and water. Water capacity considerations including time-space diagrams and queueing. Components of transportation system design, including horizontal and vertical alignment, cross sections, earthwork, drainage, and pavements. Letter grading. Mr. Brandenberg (Sp)

C182. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended prerequisites: courses C104, 108, 120, Materials Science 104. Correlation, analysis, and metri- cation of aspects of pavement design, including materials selection and production loading, and volume calculations. Special attention to aspects of pavement distress serviceability and factoring of these into metrics of pavement performance. Discussion of potential choices of materials (i.e., asphalt, cement, concrete) and their specific strengths and weaknesses in paving applications. Unification and correlation of different variables that influence pavement performance and highlight their relevance in design. Concurrently scheduled with course C282. Letter grading. Mr. Sant (Sp)

188. Special Courses in Civil and Environmental Engineering. (2 to 6) Lecture, to be arranged; outside study, eight hours. Prerequisites vary. Review of hazardous waste types and potential sources. Techniques in measuring and modeling subsurface flow and contaminant transport in subsurface. Design project illustrating remedial investigation and feasibility study. Letter grading.

Ms. Jay (Not offered 2014-15)

223. Slope Stability and Earth Retention Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 121, 220. Basic concepts of slope stability of earth slopes, including shear strength, design charts, limit equilibrium, seepage flow, analysis, staged construction, and rapid drawdown. Theory of earth pressures behind retaining structures, with special application to design of retaining walls, sheet piles, micropile stabilization earth, soil nails, and anchored and braced excavation. Letter grading. Mr. Brandenberg (W)

C184. Structure, Processing, and Properties of Structural Materials. (4) Lecture, two hours; outside study, six hours. Prerequisites: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental regulations, waste characterization, geotechnics, solid waste landfills, subsurface barrier walls, and management of high water pressure conditions. Letter grading. Mr. Sant (Sp)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 220, 245 (may be taken concurrently). Analysis of earthquake-induced ground failure, including soil liquefaction, cyclic softening of clay soils, seismic compression, surface fault rupture, and seismic slope instability. Ground response effects on earthquake ground motions. Soil-structure interaction, including inertial and kinematic interaction and foundation deformations under seismic loading. Letter grading. Mr. Stewart (Sp)

226. Geoenvironmental Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental regulations, waste characterization, geotechnics, solid waste landfills, subsurface barrier walls, and management of high water pressure conditions. Letter grading. Mr. Stewart, Mr. Vucetic (W)

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 model- ing concerns such as instability, bifurcation, non- existence, and nonuniqueness of solutions. Letter grading. Mr. Stewart, Mr. Vucetic (Sp)

M230A. Linear Elasticity. (4) Same as Mechanical and Aerospace Engineering 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; plane strain problems; plane and axisymmetric problems; plane strain problems; holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Integral and variational methods. Letter grading. Mr. Mu, Mr. Mal (F)

M230B. Nonlinear Elasticity. (4) Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course 230A. Kinematics, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displace-
ment relations; balance laws, Cauchy and Piola stresses, Cauchy's equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelectricity; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mai (W)


232. Theory of Plates and Shells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Small and large deformation theories of thin plates; energy methods; free vibrations and membrane theory of shells; axisymmetric deformations of cylindrical and spherical shells, including bending. Letter grading. Ms. Zhang (F)


234. Advanced Topics in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Limited to graduate engineering students. Current topics in composite materials, computational methods, finite element analysis, structural synthesis, nonlinear mechanics, and structural mechanics in general. Topics may vary from term to term. Letter grading. Mr. Ju (Not offered 2014-15)

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

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

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


237A. Dynamics of Structures. (4) Same as Mechanical and Aerospace Engineering M269A.) Lecture, four hours; outside study, eight hours. Requisite: course 137. Principles of dynamics. Determination of normal modes and frequencies by differential and integral equation solutions. Transient and steady state response. Emphasis on derivation, and solution of governing equations using matrix formulation. Letter grading. Mr. Bendiksen, Mr. Ju, Mr. Taciroglu (W)


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


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

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

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 concepts, hazard analysis of ground shaking. Earthquake conditions for site analysis. Seismic hazard analysis. Ground motion selection and modification for response history analysis. Letter grading. Mr. Stewart (W)

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

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 130, and M237A or 246. Concept of seismic isolation, shear theory, overturning, viscoelastic and hysteretic behavior, elastomeric bearings under compression and bending, buckling of bearings, sliding bearings, passive energy dissipation devices, response of structures with viscoelastic and energy dissipation devices, static and dynamic analysis procedures, code provisions and design methods for seismically isolated structures. Letter grading.


249. Selected Topics in Structural Engineering, Mechanics, and Geotechnical Engineering. (2) Lecture, two hours; outside study, eight hours. Requisite: course 248. In-depth study of structural mechanics and material behavior. Emphasis on recent research and developments in structural engineering, structural mechanics, and geotechnical engineering. Structural analysis, finite elements, structural stability, dynamical behavior of structures. Earthquake engineering, ground motion, elasticity, plasticity, structural mechanics, mechanics of composites, constitutive modeling, geomechanics, and geotechnical engineering. May be repeated for credit. S/U grading. Mr. Brandenberg, Mr. Stewart, Mr. Taciroglu, Mr. Wallace (F, W, Sp)

250A. Surface Water Hydrology. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150. In-depth study of surface water 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 surfaces, water flow and transport in turbulent boundary layer, basic remote sensing principles. Letter grading. Mr. Yeh (F)

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; simulation models; optimization, including linear programming, systems projects; and multiobjective planning and conjunctive use of surface water and groundwater. Emphasis on management of water quantity. Letter grading.

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

Mr. Margulis (Not offered 2014-15)

251B. Contaminant Transport in Groundwater. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic physical concepts of remote sensing as they relate to surface and atmospheric hydrologic processes. Applications include radiative transfer modeling and retrieval of hydrologically relevant parameters like topography, soil moisture, snow properties, vegetation, and precipitation. Letter grading.

Mr. Yeh (Not offered 2014-15)

251C. Remote Sensing with Hydrologic Applications. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 106A, one or more courses from Economics 1, 2, 101, 101. Economic theory and applications in analysis and management of water and environmental problems; application of price theory to water resource management and renewable resources; benefit-cost analysis with applications to water resources and environmental planning. Letter grading. Mr. Yeh (Sp)


254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture; four hours; outside study, eight hours. Requisites: Chemistry 20B, Mathematics 31A, 31B, Physics 1A, 1B. Equilibrium and kinetic descriptions of chemical processes in aquatic systems; growth and biogeochemical cycles in natural fresh/marine surface waters and in water treatment. Processes include acid-base chemistry and alkalinity (carbonate system), complexation, precipitation/dissolution, absorption oxidation/reduction, and photochemistry. Letter grading. Ms. Jay (F)

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

255B. Biological Processes for Water and Wastewater Treatment. (4) Lecture; four hours; outside study, eight hours. Requisites: courses 254A, 255A. Fundamentals of environmental engineering microbiology; growth and biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmospheric chemical processes; air pollution; chemistry and climate. S/U or letter grading.

Mr. Stenstrom (Sp)

M262A. Introduction to Atmospheric Chemistry. (4) Same as Atmospheric and Oceanic Sciences M263A. Lecture; four hours. Requisite for undergraduate Chemistry 20B. Principles of chemical kinetics, thermodynamics, spectroscopy, and photochemistry; chemical composition and history of Earth's atmosphere; radiative cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmospheric chemical processes; air pollution; chemistry and climate. Letter grading.

M262B. Atmospheric Diffusion and Air Pollution. (4) Same as Atmospheric and Oceanic Sciences M262B. Lecture; three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complexes; meteorological factors and air pollution potential; meteorological aspects of air pollution. S/U or letter grading. (Not offered 2014-15)


Mr. Stenstrom (W)

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

Mr. Stolzenbach (Sp)

265A. Mass Transfer in Environmental Systems. (4) Lecture; four hours; computer applications, two hours; outside study, eight hours. Designed for graduate environmental engineering program students. Physical, chemical, and mass transfer processes 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 2014-15)

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

Mr. Stolzenbach (Not offered 2014-15)

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

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, mineral solubility, surface complexation, 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, landfill leachate, and microbial respiration. Research/modeling project required. Letter grading. Mr. Stolzenbach (Not offered 2014-15)

C282. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture; four hours; discussion; two hours; outside study, six hours. Correlation, analysis, and metrisation of aspects of pavement design, including current interest in climate change, loading and volume. Special attention to aspects of pavement distress/serviceability and factoring of 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 paving applications. Utilization and correlation of different variables that influence pavement performance and highlight their relevance in pavement design. Concurrently scheduled with course C182. Letter grading. Mr. Sant (Sp)

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

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

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate civil engineering students. Seminars may be organized in advanced technical courses. If appropriately arranged. May be repeated with topic change. Letter grading.

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as teaching assistant, associate,
or teaching assistant in Civil and Environmental Engineering Department. Seminar on communication of civil engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids; grading, advising, and rapport with students. S/U grading.

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

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

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

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

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

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

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

Computer Science

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Demetri Terzopoulos, Ph.D. (Chancellor’s Professor)
Wei Wang, Ph.D.
Alan L. Yuille, Ph.D.
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Lixia Zhang, Ph.D. (Jonathan B. Postel Professor of Computer Systems)
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David A. Rennels, Ph.D.
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Associate Professors
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Yuval Tamir, Ph.D.

Assistant Professors
Tyson Condie, Ph.D.
Jason Ernst, Ph.D.
Alexander Sherstov, Ph.D.

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
Deborah L. Estrin, Ph.D.
David E. Heckerman, Ph.D.
Van Jacobson, M.S.
Alan C. Kay, Ph.D.
Rupak Majumdar, Ph.D.
Peter S. Pao, Ph.D.
Peter L. Reiher, Ph.D.

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Edward W. Kohler, Ph.D.
Giovanni Pau, Ph.D.

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

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

Computer Science and Engineering Undergraduate Program Objectives
The computer science and engineering program is accredited by the Engineering Accreditation Commission and the Computing Accreditation Commission of ABET, http://www.abet.org.

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 computer engineering, in related engineering or application areas, and at the interface of computers and physical systems, (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.

Undergraduate Study
The Computer Science and Engineering and Computer Science majors are designated capstone majors. Computer Science and Engineering students complete a major product design course, while Computer Science students complete either a software engineering or a major product design course. Graduates are expected to apply the basic mathematical and scientific concepts that underlie modern computer science and engineering; design a software or digital hardware system, component, or process to meet desired needs within realistic constraints; function productively with others as part of a team; identify, formulate, and solve computer software- and hardware-related engineering problems; and demonstrate effective communication skills.

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; Electrical Engineering 10, 11L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181, Electrical Engineering 102, 110, 111L; one course from Civil and Environmental Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone design course (Computer Science 152B); 12 units of elective courses selected from Electrical Engineering 113, 113DA, 113DB, 115A, 115C, 132A, 141, 181D; 12 units of

Students in Professor Jason Cong’s laboratory work on an experimental cluster with field-programmable gate array (FPGA) acceleration. This cluster can accelerate the current state-of-the-art CPU-based cluster for computation-intensive workloads.
elective courses selected from Computer Science 111 through CM187 or Electrical Engineering 133A, at least one of which must be Computer Science CM121, CM122, CM124, 143, 161, or 174A; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs.

Credit is not allowed for both Computer Science 170A and Electrical Engineering 133A unless at least one of them is applied as part of the technical breadth area. Four units of either Computer Science 194 or 199 may be applied as an elective by petition.

A multiple-listed (M) course offered in another department may be used instead of the same computer science course (e.g., Electrical Engineering M116C may be taken instead of Computer Science M151B). Credit is applied automatically.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 20 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; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major

Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181; one course from Civil and Environmental Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone software engineering or design course from Computer Science 130 or 152B; 20 units of elective courses selected from Computer Science 111 through CM187 or Electrical Engineering 133A, at least one of which must be Computer Science 112 or 170A or Electrical Engineering 133A, and at least two of which must be selected from Computer Science CM121, CM122, CM124, 143, 161, or 174A, with at least one of the two courses from 143, 161, or 174A; 12 units of science and technology courses (not used to satisfy other requirements) that may include 12 units of upper division computer science courses or 12 units of courses selected from an approved list available in the Office of Academic and Student Affairs; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs.

Students must take at least one course from Computer Science 130 or 132. Computer Science 130 or 152B may be applied as an elective only if it is not taken as the capstone course. Credit is not allowed for both Computer Science 170A and Electrical Engineering 133A unless at least one of them is applied as part of the science and technology requirement or as part of the technical breadth area. Four units of either Computer Science 194 or 199 may be applied as an elective by petition.

A multiple-listed (M) course offered in another department may be used instead of the same computer science course (e.g., Electrical Engineering M116C may be taken instead of Computer Science M151B). Credit is applied automatically.

For information on University and general education requirements, see Requirements for B.S. Degrees on page 20 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) or CM122 (or Chemistry and Biochemistry CM160B) or CM124 (or Human Genetics CM124), and one bioinformatics elective course selected from Computational and Systems Biology M186, Computer Science CM121, CM122, CM124, 170A, Ecology and Evolutionary Biology 135, Electrical Engineering 102, 141, Human Genetics C144, Molecular, Cell, and Developmental Biology 144, 172, Physiological Science 125, Statistics 100A, 100B. Eight units of either Bioinformatics 199 or 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 24.

The following introductory information is based on the 2014-15 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad
The total number of graduate courses must include both the total number of formal courses and specific courses as required, but a majority of the minimum of five graduate courses. No specific courses are required for the M.S. degree, including a minimum of five graduate courses. No specific courses are required toward 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 used to satisfy graduate degree requirements if students have already received a grade of B– or better for a 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.

**Course Requirements**

**Course Requirements**

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**

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**Course Requirements**

**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.

**Course Requirements**

**Course Requirements**

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

**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 used to satisfy graduate degree requirements if students have already received a grade of B– or better for a 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.

**Course Requirements**

**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.

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

**Computer System Architecture**

Computer system architecture deals with 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 pro-

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**Emphasis of Computer Science Theory**

- Design and analysis of algorithms
- Distributed and parallel algorithms
- Models for parallel and concurrent computation
- Online and randomized algorithms
- Computational complexity
- Automata and formal languages
- Cryptography and interactive proofs
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), multiplex chips (MCMs), system-on-a-chip (SoCs), network-on-a-chip (NoC), system-in-a-package (SiPs), and designs 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**

The graphics and vision field focuses on the synthesis and analysis of image and video data by computer. Graphics includes the topics of rendering, modeling, animation, visualization, and interactive techniques, among others, and it is broadly applicable in the entertainment industry (motion pictures and games) and elsewhere. Vision includes image/video representation and registration, feature extraction, three-dimensional reconstruction, object recognition, and image-based modeling, among others, with applications to real-time vision/control for robots and autonomous vehicles, medical imaging, visual sensor networks and surveillance, and more. Several of the projects undertaken by our researchers in this field unify graphics and vision through mathematical modeling, wherein graphics is considered a models-to-images synthesis problem and vision the converse images-to-models analysis problem.

**Information and Data Management**

The information and data management field focuses on basic problems of modeling and managing data and knowledge, and their relationship 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 laboratories and centers for instruction and research include:

**Artificial Intelligence Laboratories**

**Automated Reasoning Group**
Adnan Y. Darwiche, Director

The laboratory focuses on research in probabilistic and logical reasoning and their applications to problems in science and engineering disciplines. On the theoretical side, research involves formulation of various tasks such as diagnosis, belief revision, planning, and verification as reasoning problems. On the practical side, focus is on development of efficient and embeddable reasoning algorithms that can scale to real-world problems, and software environments that can be used to construct and validate large-scale models. See http://reasoning.cs.ucla.edu.

**Cognitive Systems Laboratory**
Judea Pearl, Director

The laboratory targets research areas concerned with evidential reasoning, the distributed interpretation of multisource data in networks of partial beliefs; learning, the structuring and parameterizing of links in belief networks to form a representation consistent with a stream of observations; constraint processing, including intelligent backtracking, learning while searching, temporal reasoning, etc.; graphoids, the characterization of informational dependencies and their graph representations; and default reasoning, use of qualitative probabilistic reasoning to draw plausible and defeasible conclusions from incomplete information. See http://cognition.cs.ucla.edu/cogsys.html.

**Computational Systems Biology Laboratories**

**Biocybernetics Laboratory**
Joseph J. DiStefano III, Director

This interdisciplinary research typically involves integration of theory with real laboratory data, using biomodeling, computational, and biosystems approaches. Problem domains are physiological systems, disease processes, pharmacology, and some post-genomic bioinformatics. Laboratory pedagogy involves development and exploitation of the synergistic and methodologic interface between structural and computational biomodeling with laboratory data, or computational systems biology, with a focus on
integrated approaches for solving complex biosystem problems from sparse biodata e.g., in physiology, medicine, and pharmacology), as well as voluminous biodata (e.g., from genomic libraries and DNA array data). See http://biocyb.cs.ucla.edu/research.html.

Computational Genetics Laboratory
Eleazar Eskin, Director
The laboratory is comprised of a computational genetics group affiliated with both the Computer Science and Human Genetics departments. Research interests are in computational genetics, bioinformatics, computer science, and statistics. The laboratory focuses on developing techniques for solving the challenging computational problems that arise in attempting to understand the genetic basis of human disease. See http://zarlab.cs.ucla.edu/about/.

Computer Systems Architecture Laboratories
Concurrent Systems Laboratory
Yuval Tamir, Director
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/cs婌research/labs/csl/.

Digital Arithmetic and Reconfigurable Architecture Laboratory
Milos D. Ercegovac, Director
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
Majid Sarrafzadeh, Director
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
Jason Cong, Director
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.

Graphics and Vision Laboratories
Center for Vision, Cognition, Learning, and Art
Song-Chun Zhu, Director
The laboratory is affiliated with the Computer Science and Statistics departments. Research begins with computer vision and expands to other disciplines. The objective is to pursue a unified framework for representation, learning, inference, and reasoning; and to build intelligent computer systems for real-world applications. Its projects span four directions: vision (object, scene, events, etc.); cognition (intentions, roles causality, etc.); learning (information projection, stochastic grammars, etc.); and art (abstraction, expression, aesthetics, etc.). See http://vcla.stat.ucla.edu.

Computer Graphics and Vision Laboratory (MAGIX)
Demetris Terzopoulos, Director
The laboratory conducts 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.cs.ucla.edu/magix.

UCLA Collective on Vision and Image Sciences

UCLA Vision Laboratory
Stefano Soatto, Director
Researchers investigate how images—i.e., measurements of light—can be used to infer properties of the physical world such as shape, motion, location, and material properties of objects. This is key to developing engineering systems that can “see” and interact intelligently with the world around them. For example, images captured by a car-mounted video camera can be processed by computers to infer a model of the car’s surroundings, e.g., other vehicles, pedestrians, etc. This technology can also be used to analyze images captured in the environment to understand the effects of climate change by monitoring the behavior of animals and plants. Analysis of images of the human body can be used both for diagnostic purposes and for planning interventions. See http://vision.ucla.edu.

Information and Data Management Laboratories

Information and Data Management Group
(Multiple Faculty)
The group is a collaboration of all UCLA faculty from the information and data management field. It is interested in multiple research areas including big data, archival information systems, knowledge discovery and data mining, Earth Science Partners’ private network, genomics graph database development, multimedia information stream system technology, Smart Space middleware architecture, and technologically based assessment of language and literacy, to name just a few. See http://www.cs.ucla.edu/idm/.

Multimedia Information System Technology Group (MIST)
Alfonso F. Cardenas, Principal Investigator
This interdisciplinary research group collaborates with the UCLA Geffen School of Medicine and its Radiological Sciences Department. The group is immersed in competitive and exciting research and development in multimedia technology and its application, multimedia database management, Internet searches for interesting information instead of simply relevant content, patent information retrieval and mining, and in general working on the fringe of technology’s cutting edge. See http://www.mist.cs.ucla.edu

Web Information Systems Laboratory
Carlo A. Zaniolo, Director
This research group investigates Web-based information systems and seeks to develop enabling technology for such systems by integrating the Web with database systems. Current research efforts include the DeAL system, a next-generation database system; SemScapo, an NLP-based framework for mining unstructured or free text; EARL (Early
**Network Systems Laboratories**

**Internet Research Laboratory (IRL)**
Lixia Zhang, Principal Investigator

The laboratory's research areas include fault tolerance in large-scale distributed systems, Internet routing infrastructure, inter-domain routing (BGP), and protocol design principles for large-scale, self-organizing systems. It is also involved in Internet security projects that include development of monitoring tools for DNS security deployment and the enabling of cryptographic defenses in large-scale distributed systems. See http://irl.cs.ucla.edu.

**Laboratory for Advanced System Research (LASR)**
Peter L. Reiher, Principal Investigator

The laboratory engages in research to develop advanced operating systems, distributed systems, middleware, and security systems. See http://www.lasr.cs.ucla.edu.

**Network Research Laboratory**
Mario Gerla, Director

The laboratory supports research projects in a broad range of topics in network communications including network protocols and architectures, modeling and analysis, wireless networks, sensor networks, car-to-car networks, peer-to-peer techniques, medical networks, and network measurement. It focuses on the use of modeling and analytical techniques to study challenging problems. See http://nrl.cs.ucla.edu.

**Wireless Networking Group (WiNG)**
Songwu Lu, Director

The laboratory’s research areas include wireless networking, mobile systems, and cloud computing. Its focus is on design, implementation, and experimentation of protocols, algorithms, and systems for wireless data networks. The goal is to build high-performance and dependable networking solutions for the wireless Internet. See http://metro.cs.ucla.edu.

**Software Systems Group**
(Multiple Faculty)

The group is a collaboration of faculty from the software systems and network systems fields. It conducts research on the design, implementation, and evaluation of operating systems, networked systems, programming languages, and software engineering tools. See http://software.cs.ucla.edu.

**Computer Science Centers**

**Center for Autonomous Intelligent Networked Systems (CAINS)**
The center was established in 2001 with researchers from several laboratories in the Computer Science and Electrical Engineering departments. It serves as a forum for intelligent-agent researchers and visionaries from academia, industry, and government, with an interdisciplinary focus on fields such as engineering, medicine, biology, and social sciences. Information and technology are exchanged through symposia, seminars, short courses, and collaboration in joint research projects sponsored by government and industry.

Research projects include use of unmanned autonomous vehicles, coordination of vehicles into computing clouds, and integration of body sensors and smart phones into m-health systems. Ongoing research encompasses personal and body networks, cognitive radios, ad hoc multihop networking, vehicular networks, dynamic unmanned backbone, underwater unmanned vehicles, mobile sensor platforms, and network coding. See http://www.cains.cs.ucla.edu.

**Center for Domain-Specific Computing (CDSC)**

CDSC was established in 2009 with the support of a $10 million grant from NSF’s Expeditions in Computing program to develop high-performance, energy-efficient, customizable computing that will revolutionize the way computers are used in healthcare and other important applications. Domain-specific computing uses customizable architectures and high-level computer languages tailored to particular application domains.

The center is a collaborative effort between UCLA’s Computer Science, Electrical Engineering, Mathematics, and Radiological Sciences departments, as well as the Computer Science and Engineering departments of Rice University, UC Santa Barbara, and Ohio State University. Its objectives are to develop a general (and largely reusable) methodology for creating novel and highly efficient customizable architecture platforms and the associated compilation tools and runtime management environment to support domain-specific computing. Health care is a significant domain because it has such a major impact on issues of national economy and quality of life; a major focus for the center is on medical imaging and hemodynamic modeling. See http://www.cdsc.ucla.edu.

**Center for Information and Computation Security (CICS)**
The center was established in 2003 to promote all aspects of research and education in cryptography and computer security. It explores novel techniques for securing national and private-sector information infrastructures across various network-based and wireless platforms as well as wide-area networks. The inherent challenge is to provide guarantees of privacy and survivability under malicious and coordinated attacks.

The center has raised federal, state, and private-sector funding, including collaboration with Israel through multiple U.S.–Israel Bina
tional Science Foundation grants. It has also attracted multiple international visiting scholars. CICS explores and develops state-of-the-art cryptographic algorithms, definitions, and proofs of security; novel cryptographic applications such as new electronic voting protocols and identification, data-rights management schemes, and privacy-preserving data mining; security mechanisms underlying a clean-slate design for a next-generation secure Internet; biometric-based models and tools, such as encryption and identification schemes based on fingerprint scans; and the interplay of cryptography and security with other fields such as bioinformatics, machine learning, complexity theory, etc. See http://www.cs.ucla.edu/security/.

**Scalable Analytics Institute (ScAI)**
The institute was established in 2013 with a focus on the continuing growth of data and demand for smart analytics to mine that data. Such analytics are creating major transformative opportunities in science and industry. To fully capitalize on these opportunities, computing technology must solve the three-pronged challenge created by the exploding size of big data, the growing complexity of big data, and the increased sophistication of analytics that can be used to extract patterns and trends from the data. Accordingly, the center focuses on big data, data mining bioinformatics, computational biology, knowledge-based systems, database systems, non-monotonic reasoning, and spatiotemporal reasoning.

**Wireless Health Institute (WHI)**

Wireless health is by far the most comprehensive merging of medicine and technology yet conceived. No prior field has so broadly
addressed the urgent needs of health care quality, health care delivery, and individual patient needs with matching technology solutions. And at no prior time has the cost of physiological monitoring products been lower or the availability of wireless network access been more universally ubiquitous. Created to take an active part in this new research field and industry, the institute is focused on advancing the quality and accessibility of health care.

WHi is comprised of individuals from many fields of medicine, nursing, molecular and medical pharmacology, and public health, in addition to the VA Greater Los Angeles Healthcare System and the UCLA Anderson Graduate School of Management, College of Letters and Science, and Henry Samueli School of Engineering and Applied Science. Multidisciplinary collaborations over the last 10 years have established a leadership position for UCLA, with specific research objectives related to health and wellness, disease management, rehabilitation, and geriatric care. See http://www.wirelesshealth.ucla.edu.

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 departmental 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 1000, 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 802.11n 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 Com-

munications 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

Junghoo (John) Cho, Ph.D. (Stanford, 2002)

Databases, web technologies, information discovery and integration

Jingcheng Cong, Ph.D. (U. 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. Darwech, Ph.D. (Stanford, 1993)

Knowledge representation and automated reasoning (symbolic and probabilistic), applications to diagnosis, prediction, planning, and verification

Joseph J. DiStefano III, Ph.D. (UCLA, 1966)

Biocybernetics; computational systems biology; dynamic biosystems modeling, simulation, clinical therapy and experiment design optimization methodologies; pharmacokinetic (PK), pharmacodynamic (PD), and physiologically-based PK (PBPK) modeling; knowledge-based expert systems for life science research

Michael G. Dyer, Ph.D. (Yale, 1982)

Artificial intelligence: natural language processing; connectionist, cognitive, and animat-based modeling

Micos D. Ercegovac, Ph.D. (U. Illinois, 1975)

Application-specific architectures, digital computer arithmetic, digital design, low-power systems, reconfigurable systems

Eleazar Eskin, Ph.D. (Columbia, 2002)

Bioinformatics, genetics, genomics, machine learning

Elizer 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 works, personal-area networks (Bluetooth and Zigbee), underwater sensor networks, Internet transport protocols (TCP streaming), internet path characterization, capacity and bandwidth estimates, analytical and simulation models for network and protocol performance evaluation


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. (U. Illinois, 1998)

Integrated access support over heterogeneous networks, e.g., mobile computing environ-
ments, Internet and ActiveNet: networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics


Scientific computing and applied mathematics

Retail 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)

Compilers, embedded systems, programming languages

D. Stott Parker, Jr., Ph.D. (U. Illinois, 1978)

Data mining, information modeling, scientific computing, bioinformatics, database and knowledge-based systems

Miodrag Potkonjak, Ph.D. (UC Berkeley, 1991)

Computer-aided analysis and synthesis of system level designs, behavioral synthesis, and interaction between high-performance application-specific computations and communications

Glenn D. Reiman, Ph.D. (UC San Diego, 2001)

Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, multicore and multiprocessor design

Amit Sahai, Ph.D. (MIT, 2000)

Theoretical computer science, cryptography, computer security, algorithms, error-correcting codes and learning theory

Majid Sarrafzadeh, Ph.D. (U. Illinois, 1987)

Computer engineering, embedded systems, VLSI CAD, algorithms

Stefano Soatto, Ph.D. (Caltech, 1996)

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

Mari B. Srivastava, Ph.D. (UC Berkeley, 1992)

Energy aware networking and computing, embedded networked sensing, embedded software, low-power wireless systems and applications of wireless and embedded technology

Demetri Terzopoulos, Ph.D. (MIT, 1984)

Computer graphics, computer vision, medical image analysis, computer-aided design, artificial life/intelligence

Wei Wang, Ph.D. (UCLA, 1999)

Data mining, biometrics and computational biology, databases


Computer vision, computational models of cognition, machine learning

Carlo A. Zaniolo, Ph.D. (UCLA, 1976)

Knowledge bases and deductive databases, parallel execution of PROLOG programs, formal software specifications, distributed systems, big data, artificial intelligence, and computational biology

Lixia Zhang, Ph.D. (MIT, 1989)

Computer network, Internet architecture, protocol designs, security and resiliency of large-scale systems

Song-Chun Zhu, Ph.D. (Harvard, 1996)

Computer vision, statistical modeling and computing, vision and visual arts, machine learning

* Also Professor of Mathematics
Professors Emeriti
Alfonso F. Cardenas, Ph.D. (UCLA, 1969) Database management, distributed heterogeneous and multimedia (text, image/picture, video, voice) systems, information systems planning and design, methodologies, software engineering, medical informatics, legal and intellectual property issues
Richard R. Muntz, Ph.D. (Princeton, 1969) Distributed computing, distributed database, memory management, computer communications, performance measurement and evaluation for distributed systems and multiaccess packet-switched systems
Allen Klinger, Ph.D. (UC Berkeley, 1966) Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability
Allen Klinger, Ph.D. (U.C Berkeley, 1966) Pattern recognition, picture processing, biomedical applications, mathematical modeling
Lawrence P. McNamee, Ph.D. (U. Pittsburgh, 1964) Computer graphics, discrete simulation, digital filtering, computer-aided design, LSI fabrication techniques, integrated circuit board design
Judea Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1966) Artificial intelligence, philosophy of science, reasoning under uncertainty, causality inference, causal and counterfactual analysis
David A. Rennels, Ph.D. (UCLA, 1973) Digital algorithms and architecture; design, fault-tolerant computing, digital arithmetic
*Jacques J. Vidal, Ph.D. (U. Paris-Sorbonne, France 1961) Information processing in biological systems, with emphasis on neuroscience, cybernetics, online laboratory computer systems, and pattern recognition, analog and hybrid systems' signal processing
Associate Professors
Todd D. Millstein, Ph.D. (U. Washington, 2003) Programming language design, static type systems, formal methods, software model checking, compilers
Yuval Tamir, Ph.D. (UIC Berkeley, 1985) Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection network protocols and switches, multi-core architectures, reconﬁgurable systems
Assistant Professors
Tyoan Condie, Ph.D. (UC 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. (U. Texas Austin, 2009) Complexity theory with a focus on communication and circuit complexity, computational learning theory, quantum computing
Senior Lecturers S.O.E.
Paul R. Eggert, Ph.D. (UCLA, 1980) Programming languages, operating systems principles, compilers, Internet
David A. Smallberg, M.S. (UCLA, 1978) Programming languages, software development
Senior Lecturer S.O.E. Emeritus
Leon Levine, M.S. (MIT, 1949) Computer methodology
Adjunct Professors
Deborah L. Estrin, Ph.D. (MIT, 1985) Sensor networks, network sensing, environmental monitoring, computer networks
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, M.S. (U. Arizona, 1972) Named data network (NDA), content-centric networking
Alan Kay, Ph.D. (U. 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
M. Yanha Sanadidi, Ph.D. (UCLA, 1982) Computer networking; path characteristics estimation and applications in flow control, adaptive streaming and overlays design, probability models of computing systems, algorithms and networks
Adjunct Associate Professors
Edward W. Kohler, Ph.D. (MIT, 2001) Operating systems, software architecture, network measurement, network protocol design, programming language techniques for improving systems software
Giovanni Pau, Ph.D. (U. Bologna, Italy, 1998) Protocol design implementation and evaluation for QOS support for wireless/wireline networks and vertical handover protocols and architectures
Adjunct Assistant Professors
Carey S. Nachenberg, M.S. (UCLA, 1995) Anti-virus and intrusion detection technology
Ani Nahapetian, Ph.D. (UCLA, 2007) Hardware-based security system, embedded systems, mobile and wireless networks; algorithms for reconﬁgurable computing

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

Upper Division 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. Culminating paper required. May be repeated for credit. Individual contract required. Letter grading.

Computer Science
Lower Division Courses
1. Freshman Computer Science Seminar. (1) Seminar, one hour; discussion, one hour. Introduction to department resources and principal topics and key ideas in computer science and computer engineering. As assignments given to bolster independent study and writing skills. Letter grading.
2. 2. Great Ideas in Computer Science. (4) Lecture, four hours; outside study, eight hours. Broad coverage for liberal arts and social sciences students of computer science theory, technology, and implications, including artificial and neural machine intelligence, computability limits, virtual reality, cellular automata, artiﬁcial life, programming languages survey, and philosophical and societal implications. P/NP or letter grading.
19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of artiﬁcial 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.

M. Yahya Sanadidi, Ph.D. (UCLA, 1982)

1. Freshman Computer Science Seminar. (1) Seminar, one hour; discussion, one hour. Introduction to department resources and principal topics and key ideas in computer science and computer engineering. As assignments given to bolster independent study and writing skills. Letter grading.

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

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of artificial 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.


M. Yahya Sanadidi, Ph.D. (UCLA, 1982)

1. Freshman Computer Science Seminar. (1) Seminar, one hour; discussion, one hour. Introduction to department resources and principal topics and key ideas in computer science and computer engineering. As assignments given to bolster independent study and writing skills. Letter grading.

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

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of artificial 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.


M. Yahya Sanadidi, Ph.D. (UCLA, 1982)

Mr. Palsberg, Mr. Reinman (F,Sp)

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

Mr. Eggert, Mr. Palsberg (F,W,Sp)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical Engineering M116.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of algorithmic systems. Random variables, conditional probability, probability density and distribution, normalization, expected value, variance, standard deviation, and higher moments. Bayes theorem, Markov chains. Letter grading.

Mr. Eskin (Not offered 2014–15)

M117. Computer Networks: Physical Layer. (4) (Same as Electrical Engineering M117.) Lecture, two hours; discussion, two hours; laboratory, two hours; outside study, six hours. Not open to students with credit for course M171L. Introduction to wireless networking. Letter grading.

Mr. Gerla (Not offered 2014–15)

Upper Division Courses


Mr. Eggert (F,W,Sp)

112. Modeling Uncertainty in Information Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisites: course 111 and one course: Lecture/Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for juniors/seniors. Probability and stochastic process models as applied in computer science. Basic mathematical tools include random variables, conditional probability, expectation and higher moments, Bayes theorem, Markov chains. Applications include probabilistic algorithms, evidential reasoning, analysis of algorithms and data structures, complexity, and formal protocol and queueing models. Letter grading.

Mr. Gerla, Ms. Vaughan (W,Sp)

114. Peer-to-Peer Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 118. 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 Television (IPTV) applications, with emphasis on thin clients (such as set-top boxes and thin-client PC's). Introduction to mesh-based and tree-based topologies for live streaming, with emphasis on key aspects of peer selection metrics and illustration of common optimization techniques (e.g., tree pruning and delay). Hands-on approach to guide students to development and testing of actual experimental system on PlanetLab. Letter grading.

Mr. Gerla (Not offered 2014–15)

115. Introduction to Computer Security. (4) Lecture, four hours; discussion, two hours; laboratory, two hours; outside study, six hours. Enforced prerequisites: courses 33, 35L. Basic concepts in design and use of computer security. Topics may include cryptography, authentication/authorization, cryptography, network security, and various other topics as approved. Letter grading.

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

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

Mr. Gerla, Ms. Zhang (F,W,Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Enforced prerequisite: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, 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 bioinformatics and emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course C221 or C221J. Advanced biostatistics. Letter grading.

Mr. Eskin (Not offered 2014–15)

CM122. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Enforced prerequisite: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, 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. Development and application of computational approaches to better focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include the formal language and theory of computer science. Concurrently scheduled with course CM222. Letter grading.

Mr. Eskin (F)

CM124. Computational Genetics. (4) (Same as Human Genetics CM124.) Lecture, four hours; discussion, two hours. Enforced prerequisite: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for engineering students as well as those from biological sciences and medical schools. Introduction to computational analysis of genetic variation and computational interdisciplinary research in genetics. Topics include introduction to genetics, identification of Disease, investigating human population history, technologies for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and solving those problems using computational techniques from statistics and computer science. Concurrently scheduled with course CM224. Letter grading.

Mr. Eskin (Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced prerequisite: course 111. Recommended: Engineering 183EW or 185EW. Structured programming, program specification, modularity, object-oriented programming, abstract data types, file management, debugging, software tools, software control systems, program testing, team programming. Letter grading.

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

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced prerequisites: courses 33, 35L. Basic concepts in design and use of programming languages, including abstraction, function, object-oriented, and logic programming. Letter grading.

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

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: courses 113, 181. Compiler structure; lexical and syntactic analysis; semantic analysis and code generation; devices and techniques. Letter grading.

Mr. Eggert, Mr. Palsberg (F,Sp)

133. Parallel and Distributed Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: courses 113 (may be taken concurrently). Distributed memory shared memory and shared memory parallel architectures; asynchronous parallel languages; MPI, Mosaic; primitives for parallel computation; specification of parallelism, interprocess communication and copying of variables. Letter grading.

Mr. Peng (W)

136. Introduction to Computer Security. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 113. Different programming language paradigms provide dramatically different ways of thinking about computation and offer trade-offs on many dimensions, such as modularity, extensibility, expressiveness, and safety. Concrete exploration of three major programming languages: abstraction, modularity, object-oriented, and logic programming—by prototyping implementations of languages in each. Analysis of prototypes to shed light on design and structural properties of each language and paradigm and to allow easy comparison against one another. Hands-on experience implementing new abstractions, both as stand-alone languages and as libraries in existing languages. Concurrently scheduled with course C212. Letter grading.

Mr. Peng (W)

C137A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 113. Introduction to basic concepts of information security necessary for students to understand risks and mitigations associated with protection of systems and data. Topics include symmetric and public key cryptography, security threats and risk analysis, access control and authentication/authorization, cryptography, network security, secure application design, and ethics and laws. Letter grading.

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

C137B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced prerequisite: course C137A. Study of various programming language design, implementation, theory, and practice. Emphasis is on understanding those problems using computational techniques from statistics and computer science. Concurrently scheduled with course CM224. Letter grading.

Mr. Eskin (Sp)

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M171L. Communication Systems Laboratory. (2 to 4) (Same as Electrical Engineering M171L.) Lecture, four hours; laboratory, two hours outside study, two hours. Recommended prerequisite: course M51A or Electrical Engineering M16. Recommended courses 111, and M152A or Electrical Engineering M116L. Computer system organization and design, imple- mentation of CPU datapath and control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/ output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Reinman, Mr. Tamir (W, Sp).


M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical Engineering M116L.) Laboratory, four hours; outside study, two hours. Taught by Mr. Sarrafzadeh. Enforced prerequisite: course M51A or Electrical Engineering M16. Hands-on design, implementation, and debug- ging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits using pro- grammed array logic, design projects. Letter grading. Mr. Sarrafzadeh (F, Sp).

152B. Digital Design Project Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Sarrafzadeh. Enforced prerequisite: course M152B or Electrical Engineering M116B. Recommended: En- gineering 177C. Enforced requisite to the course: learning and implementation of complex digital subsystems using field-programmable gate arrays (e.g., processors, special-purpose processors, device controllers, and input/output controllers) working in teams to develop and implement designs and to document and give oral presentations of their work. Letter grading. Mr. Sarrafzadeh (F, Sp).

abstractions, and/or programming environments. Concurrently scheduled with course C274C. Letter grading. Mr. Millstein.

143. Database Systems. (4) Lecture, four hours; lab- oratory, two hours; outside study, six hours. Taught by Mr. Cardenas, Mr. Zaniolo (F, W, Sp).

144. Web Applications. (4) Lecture, four hours; dis- cussion, two hours; outside study, six hours. Taught by Mr. Cardenas, Mr. Zaniolo (F, W, Sp).

145. Introduction to Data Mining. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Cardenas, Mr. Zaniolo (F, W, Sp).

150. Programming Reuse. (3) Lecture, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Cardenas, Mr. Zaniolo (F, W, Sp).

170. Mathematical Modeling and Methods for Computer Science. (4) Lecture, four hours; labora- tory, two hours; outside study, six hours. Taught by Mr. Korf (W, Sp).

170A. Mathematical and Computational Methods for Computer Science. (4) Lecture, four hours; labora- tory, two hours; outside study, six hours. Taught by Mr. Korf (W, Sp).

174A. Introduction to Computer Graphics. (4) Lec- ture, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Soatto (F). Taught by Mr. Soatto (W). Taught by Mr. Soatto (Sp). Taught by Mr. Soatto (Not offered 2014-15). Taught by Mr. Soatto (Not offered 2014-15).

174B. Introduction to Computer Graphics: Three-Dimensional Rendering and Photography. (4) Lec- ture, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Soatto (F). Taught by Mr. Soatto (W). Taught by Mr. Soatto (Sp). Taught by Mr. Soatto (Not offered 2014-15). Taught by Mr. Soatto (Not offered 2014-15).

174C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Soatto (F).

180. Introduction to Algorithms and Complexity. (4) Lecture, four hours; discussion, two hours; out- side study, six hours. Taught by Mr. Terzopoulos (W). Taught by Mr. Terzopoulos (Sp).

181. Introduction to Formal Languages and Au- tomat Theory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Taught by Mr. Ostrovsky, Mr. Sahai (W, Sp).

184. Introduction to Computational and Sys- tems Biology. (2) (Same as Bioengineering M184 and Computational and Systems Biology M184.) Lecture, two hours; outside study, four hours. Taught by Mr. DiStefano (F). Taught by Mr. DiStefano (W). Taught by Mr. DiStefano (Sp). Taught by Mr. DiStefano (Not offered 2014-15).

CM186. Computational Systems Biology: Mod- eling and Simulation of Biological Systems. (5) (Formerly numbered CM186B.) (Same as Bioen- gineering CM186 and Computational and Systems Bi- ology M186.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Taught by Mr. Elec- trical Engineering 102. Dynamic biosystems mod- eling and computer simulation methods for studying biological/biomedical processes and systems at mul- tiple levels of organization. Control system, multi- compartmental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural mod- eling methods applied to life sciences problems at molecular and cellular (biochemical networks), organ, and organismic levels. Both theory- and data- driven modeling, with focus on translating biomod- eling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with mod- eling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286. Letter grading. Mr. DiStefano (F).
188. Special Courses in Computer Science. (4)
Lecture, four hours; discussion, two hours; outside study, six hours. Special topics in computer science for undergraduate students that have been approved by the department chair and who have demonstrated the interest and prerequisites for the special topic. The course may be repeated for credit with approval. Letter grading.

194. Research Group Seminars: Computer Science. (4)
Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research groups in the field of computer science. May be repeated for credit with approval. Letter grading.

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

202. Advanced Computer Science Seminar. (4)
Seminar, four hours; outside study, eight hours. Preparation: completion of major field examination in computer science. Designed for graduate students, in depth study of topics in computer science and research into theory of, analysis and synthesis of, and applications of information processing systems. Each member completes one tutorial and one or more original projects. Open to all graduate students. Open to all graduate students who have completed the major field examination. S/U grading.

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

212A. Queueing Systems Theory. (4)
Lecture, four hours; outside study, eight hours. Requisites: course 112, Electrical Engineering 131A. Resource sharing issues and theory of queuing (waiting-line) systems. Review of Markov chains and basic queuing theory. Method of stages, M/G/1, E/M/1, Bulk arrival and bulk service systems. Series-parallel stages. Fundamentals of open and closed queueing networks. Intermediate queuing theory: M/G/1; G/M/m. Collectives. Advanced queuing theory: Q/G/1; Lindsey's formulae, G/G/1, and network of queues. Basis bounds, approximations. Letter grading. Mr. Gerla

212B. Queueing Applications: Scheduling Algorithms and Queueing Networks. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 212A. A practical application of queueing theory. Analysis of the traffic flow, Java-based simulation and solution of queueing scheduling algorithms: FB, Round Robin, Conserva tion Law, Bounds. Queueing networks: definitions; job flow balance; product form solutions—local balance, M/M/m policy, performance measures; asymmetric behavior and bounds; approximation techniques—diffusion—iterative techniques; applications. Letter grading. Mr. Muntz

213A. Embedded Systems. (4)
(Same as Electrical Engineering M213A.) Lecture, four hours; outside study, eight hours. Requisite: course 111. Designed for graduate computer science and electrical engineering students. Methodologies and technologies for design of embedded systems. Topics include hardware and software platforms for embedded systems, techniques for modeling and specification of system behavior, software organization, real-time operating system scheduling, real-time communication and packet scheduling, low-power battery and energy-aware system design, timing synchronization, fault tolerance and debugging, and techniques for hardware-software co-design. Letter grading. Theoretical foundations as well as practical design methods. Letter grading. Mr. Potkonjak, Mr. Srivastava

213B. Energy-Aware Computing and Cyber-Physical Systems. (4) (Same as Electrical Engineering M202B.) Lecture, four hours; outside study, eight hours. Requisite: course M51A or Electrical Engineering M16. Recommended: courses 111 and M151B or Electrical Engineering M116. System-level management and cross-layer methods for power and energy consumption in computing and communication at various scales ranging across embedded, mobile, sensor, and data-center scale. Computing, networking, sensing, and control technologies and algorithms for improving energy sustainability in human-cyber-physical systems. Topics include modeling of energy consumption, energy sources, and energy storage; dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware scheduling; low-power protocols; battery modeling and management; energy assessment; M/M/c; computing, network and system optimization. Theory and implementation. Letter grading. Ms. Estrin, Mr. Srivastava

214. Data Transmission in Computer Communications. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 112. Designed for graduate computer science students. Discrete data streams, formats, rates, transmissions; digital data transmissions via analog signaling in computer communication; media characteristics, system behavior, performance analysis; modem designs; physical interfaces in computer communication links; national/international standards; tests and measurements. Letter grading. Mr. Carlyle

215. Computer Communications and Networks. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 112. Resource sharing; computer traffic characteristics; multiplexing; network structure; packet switching and other switching techniques; ARPANET and other computer network examples; network delay and analysis; network design and optimization; network protocols; routing and flow control; satellite and ground radio packet switching; local networks; commercial network services and architectures. Optional topics include extended error control techniques; modems; SDL, HDLC, X.25, etc.; protocol design and implementation; integrated networks; communication processors. Letter grading. Mr. Chu

216. Distributed Multiaccess Control in Networks. (4)
Lecture, four hours; outside study, eight hours. Requisites: course 215, Electrical Engineering 110, Algorithms in Bioinformatics and Systems Biology. (Same as Bioinformatics M260B and Computer Engineering M127B.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, 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 bioinformatics, the design and implementation of computer systems and applications. Emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM222. S/U or letter grading. Mr. Eskin (Not offered 2014–15)

217A. Internet Architecture and Protocols. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 118. Focus on mastering existing core set of Internet infrastructure and core Internet protocols, routing protocols, DNS, NTP, and security protocols such as DNSSEC, to understand principles behind design of these protocols, appreciate their design choices, and learn lessons from their operations. Letter grading. Ms. Zhang (F)

217B. Advanced Topics in Internet Research. (4)
Lecture, four hours; outside study, eight hours. Requisite: course 217A. Designed for graduate students. Overview of Internet development history and fundamental principles underlying TCP/IP protocol design. Discussion of current Internet research topics, including latest research results in routing protocols, transport protocols, network measurements, network security protocols, and clean-slate approach to network architecture design. Fundamental issues in network protocol design and implementations. Letter grading.

218. Advanced Computer Networks. (4)
Lecture, four hours; outside study, four hours. Review of current literature in area of computer systems modeling 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. Ms. Estrin, Mr. Liu (Not offered 2014–15)

221. Introduction to Bioinformatics. (4) (Same as Bioinformatics M260A, Chemistry CM260A, and Human Genetics CM260A.) Lecture, four hours; discussion, two hours. Enforced requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, 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 bioinformatics, the design and implementation of computer systems and applications. Emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM222. S/U or letter grading. Mr. Eskin (Not offered 2014–15)

222. Algorithms in Bioinformatics and Systems Biology. (4) (Same as Bioinformatics M260B and Chemistry CM260B.) Lecture, four hours; discussion, two hours. Enforced requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, 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. Development and application of computational biological algorithms. Emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM212. Letter grading. Mr. Eskin (Not offered 2014–15)

224. Computational Genetics. (4) (Same as Bioinformatics M224 and Human Genetics CM224.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 110A, Civil Engineering 110, Electrical Engineering 131A, 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 bioinformatics, the design and implementation of computer systems and applications. Emphasis on concepts and inventing new computational and statistical techniques to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM222. Letter grading. Mr. Eskin (Not offered 2014–15)
233B. Verification of Concurrent Programs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 233A. Formal techniques for verification of concurrent 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 and hierarchical reasoning. Letter grading. Mr. Cong

234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Introduction to and practice of formal methods for designing and verifying concurrent 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 and hierarchical reasoning. Letter grading. Mr. Bagrodia

235. Advanced Operating Systems. (4) Lecture, four hours; preparation: C++ programming experience. Requisite: course 111. In-depth investigation of operating systems issues through guided construction of a research operating system for PC machines. Topics include memory management and protection, interrupts and traps, processes, interprocess communication, preemptive multitasking, file systems. Virtualization, networking, parallelism, research operating systems. Senior lab projects, including extra challenge work. Letter grading. Mr. Eggert (Not offered 2014-15)

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, common security tools, use of cryptographic protocols for security, security tools (firewalls, virtual private networking systems, secure shell), virus and worm protection, security assurance and testing, design of secure programs, privacy, applying security principles to realistic problems, and new and emerging threats and security tools. Letter grading. Mr. Palisberg, Mr. Reiher

245A. Intelligent Information Systems. (4) Lecture, discussion, 30 minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/pictures, video, and audio content. Querying, visual languages, and communication. Database design and organization, logical and physical. Indexing methods. 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 query scheduling, transaction management, fault recovery techniques, network partitioning, strong and weak concurrency control, commit protocols, semantic query answering, multibase database systems, fault recovery techniques, network partitioning, examples, trade-offs, and design experiences. Letter grading. Mr. Chu

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

246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 112, 143, 180, 181. Designed for graduate students. Scale of Web data requires novel algorithms and principles for their management and retrieval. Study of Web caching, management techniques needed to build computer systems suitable for Web environment. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh techniques, Web
tion of language and world knowledge (for instance, via back propagation and 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: courses 130 or 131 or 161. Animats are mobile/sensing animal-like software agents embedded in simulated dynamic environments. Emphasis on modeling: goal-oriented behavior, controllers, adaptation via reinforcement learning, evolutionary programming. Animat-based tasks include foraging, mate finding, predation, navigation, predator avoidance, cooperative nest building, communication, and perceptual 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 applications to planning, diagnosis, and theorem verification, and reliability analysis. Letter grading. Mr. Darwiche (Sp)


M266B. Statistical Computing and Inference in Vision and Image Science. (4) (Same as Statistics M232B.) 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, data mining. Topics include Markov chain Monte Carlo computing, sequential Monte Carlo methods, belief propagation, 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 neuroanatomy and synaptic and membrane properties 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 analyzing research in one area of interest. Letter grading.

Mr. Vidal

267B. Artificial Neural Systems and Connectionist Computing. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Analysis of major connectionist computing paradigms and underlying models and algorithms and representation. Examination of past and current implementation 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 final project research in one area of interest. Letter grading.

Mr. Vidal

268B. Machine Perception. (4) (Formerly numbered 268.) (Same as Electrical Engineering M206B.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to computational aspects of processing visual and other sensory information. Unified treatment of early vision in man and machine. Integration of symbolic and iconic representations in process of pattern recognition and machine learning that are used in computer vision, image processing, statistics, and computational biology. Topics include Bayesian decision theory, para- metric and nonparametric learning, clustering, complexity (VC-dimension, MDL, AIC), PCA/ICA/TOA, SVM, boosting, S/U. Letter grading. Mr. Soatto (Not offered 2014-15)

268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for graduate students undertaking thesis 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, multimodal sensory integration, and robotics. May be repeated for credit. S/U grading.

269. Seminar: Current Topics in Artificial Intelligence. (4) Seminar, to be arranged. Review of current literature and research in an area of artificial intelligence 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. Mr. Soatto, Ms. Vaughan (F)

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

Mr. Carlyle


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

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

Mr. Zhu


274C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. Introduction to computer animation, including polygonal character modeling, forward and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particulate systems, a course concurrently scheduled with course C174C. Letter grading. Mr. Terzopoulos (Not offered 2014-15)

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 174A. Recommended: course 161. Investigation of important role that concepts from artificial life, emerging discipline that spans computational and biological sciences, can play in construction of advanced computer graphics and vision models for virtual reality, animation, interactive games, active vision, sensor networks, medical image analysis, etc. Focus on computational models that simulate variety of living things (plants and animals) from lower animals to humans. Exposure to effective computational modeling of natural phenomena of life and their incorporation into sophisticated, self-animating graphic 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 M239.) Lecture, four hours; outside study, three hours. Designed for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are used in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, clustering, complexity (VC-dimension, MDL, AIC), PCA/ICA/TOA, SVM, boosting, S/U, S. 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. Topics in human-computer communication: interaction with pictorial information systems, sound and symbol generation by humans and machines, semantics of data, systems for speech recognition and understanding. Use of speech and text for computer input and output in applications. Letter grading.

M278. Probabilistic Models of Cognition. (4) (Same as Statistics M239.) Seminar, three hours; discussion, one hour. Requisites: course 180, Mathematics 33A, Statistics 100B. Modeling aspects of human cognition, designing artificial intelligence systems. Introduction to conceptual foundations and basic mathematical 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 and discussion of recent advancements in a host of computer science methodologies 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.
Course 280A. Algorithms. (4 each) Lecture, four hours; discussion, two hours; recitation, two hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections from design, analysis, optimization, and implementation of algorithms; complexity and general theory of algorithms; algorithms for particular application areas. Subtitles of some current sections: Principles of Data and Analysis (280A); Distributed Algorithms (280B); Biological Networks (280C). May be repeated for credit with consent of instructor and topic change. Letter grading.

Course 280AP. Approximation Algorithms. (4) Lecture, four hours; discussion, two hours; recitation, two hours. Requisite: course 180. Emphasis on theoretically sound techniques for dealing with NP-hard problems. Inability to solve these problems efficiently means algorithmic techniques are based on approximation algorithms that are provable near-optimal in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include primal-dual method, linear program rounding, greedy algorithms, and local search. Letter grading.

Course 281A. Computability and Complexity. (4) Lecture, four hours; discussion, two hours; recitation, two hours. Requisite: course 181 or compatible background. Introduction to fundamental issues of discrete information systems; theoretical sound techniques for dealing with NP-hard problems. Inability to solve these problems efficiently means algorithmic techniques are based on approximation algorithms that are provable near-optimal in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include primal-dual method, linear program rounding, greedy algorithms, and local search. Letter grading.

Course M282A. Cryptography. (4) Same as Mathematics M209A.) Lecture, four hours; discussion, two hours; recitation, two hours. Requisite: course 181. Finite-state machines, transducers, and their generalizations; regular expressions, transduction expressions, realizability; decomposition, synthesis, and design considerations; topics include homomorphisms and fault diagnosis, linear machines, probabilistic machines, applications in coding, communication, computing, system modeling, and simulation. Letter grading.

Course M282B. Cryptographic Protocols. (4) Same as Mathematics M209B.) Lecture, four hours; discussion, two hours; recitation, two hours. Requisite: course M282A. Consideration of advanced cryptographic protocol design and analysis. Protocols include noninteractive zero-knowledge proofs; zero-knowledge arguments; concurrent and non-black-box zero-knowledge; IP=PSPACE proof, stronger notions of security for public key encryption, including chosen-ciphertext security; secure multiparty computation; dealing with dynamic adversary; nonmalieability and composability of security protocols; software protection; threshold cryptography; identity-based cryptography; private information retrieval; protection against man-in-the-middle attacks; voting protocols; identification protocols; digital cash schemes; lower bounds on use of one-way functions, zero-knowledge proofs, and oblivious transfer. May be repeated for credit with topic change. Letter grading.

Course M283A-M283B. Topics in Applied Number Theory. (Same as Mathematics M284A-M284B.) Lecture, four hours; discussion, two hours; recitation, two hours. Requisite: course 180. Emphasis on topics relevant to cryptography, such as algorithmic complexity of cryptosystems, elliptic curve cryptography, quantum computing, and homomorphic encryption. Problem sets and presentation of previous and original research related to course topics. Letter grading.

Course 2890A. Online Algorithms. (4) Lecture, four hours; discussion, two hours. Requisite: course 280A. 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.

Course 289RA. Randomized Algorithms. (4) Lecture, four hours; discussion, two hours. Basic concepts and design techniques for randomized algorithms, such as probability theory, Markov chains, random walks, and probabilistic methods. Applications to randomized algorithms in data structures, graph theory, computational geometry, number theory, and parallel and distributed systems. Letter grading.

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

Course M296B. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) Same as Bioengineering M296B, Biomathematics M270, and Medicine M270D.) Lecture, four hours; discussion, eight hours. Requisite: course CM286 or M289A or Biometrics 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.

Course M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) Same as Bioengineering M296C, Biomathematics M270, and Medicine M270E.) Lecture, four hours; discussion, eight hours. Requisite: course CM286 or M289A or Biometrics 220. Exploration of current research in such areas as algorithmic complexity, one-way functions, amplification, problem set and presentation of previous and original research related to course topics. Letter grading.

Course M296D. Introduction to Computational Cardiology. (4) Same as Bioengineering M296D.) Lecture, four hours; discussion, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological processes. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and two-dimensional cardiac tissues. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.

Course 298. Research Seminar: Computer Science. (2 to 4) Seminar, two to four hours; discussion, four to six hours. Designed for graduate computer science students. Discussion of advanced topics and current research in algorithmic processes that describe and
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 Geffen School of Medicine, Graduate School of Education and Information Studies, School of Theater, Film, and Television, and College of Letters and Science.

Scope and Objectives

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There are three primary research areas in the department: circuits and embedded systems, physical and wave electronics, and 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.

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 participating 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 adapt to 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 provides all Electrical Engineering majors with preparation in the mathematical and scientific disciplines that lead to a set of courses that span the fundamentals of the discipline in the three major departmental areas of signals and systems, circuits and embedded systems, and physical wave electronics. These collectively provide an understanding of inventions of importance to society, such as the electrical grid, integrated circuits, photonic devices, automatic computation and control, and telecommunication devices and systems.

Students are encouraged to make use of their electrical engineering electives and a two-term capstone design course to pursue deeper knowledge within one of these areas according to their interests, whether for graduate study or preparation for employment. Students may further specialize by making use of their three courses in the technical breadth area (12 units required). For example, students wishing to specialize in computer engineering may select Computer Science 33 instead of Electrical Engineering 101B under the major, are encouraged to take Computer Science 35L, and then take three 4-unit upper division computer science elective courses. Students wishing to specialize in bioengineering and informatics may pursue some combination of Bioengineering 100, C101, CM102, 110, and Chemistry and Biochemistry 20B, together with elective courses such as Electrical Engineering 114, 133B, and 180DA and 180DB (the capstone design sequence).

Preparation for the Major
Required: Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical Engineering 2, 3, 10, 11L, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.
Students wishing to specialize in computer engineering are encouraged to take Computer Science 35L in preparation for upper division computer science courses.

The Major

Required: Electrical Engineering 101A, 101B (or Computer Science 33), 102, 110, 111L, 113, 115A, 115AL, 121B, 131A, 132A, 133A, 141, 170A; 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), consisting of either three additional upper division electrical engineering courses, or two upper division electrical engineering courses and one upper division computer science course; and one two-term electrical engineering capstone design course (8 units).

For information on University and general education requirements, see Requirements for B.S. Degrees on page 20 or http://www.registrar.ucla.edu/ge/.

Graduate Study

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

The following introductory information is based on the 2014-15 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasas/library/pgmrintro.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. Prerequisite. 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 codesign; and computer-aided design methodologies. 

Physical and Plasma 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


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 communication 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


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, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

Course Requirements

The selection of courses for the Ph.D. program 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. Normally, students take additional courses to acquire deeper and broader knowledge in preparation for the dissertation research.

The minimum requirements for the Ph.D. degree are as follows:

1. Requisite. M.S. degree in Electrical Engineering or a related field granted by UCLA or by an institution recognized by the UCLA Graduate Division

2. All Ph.D. program requirements should be completed within five academic years from admission into the Ph.D. graduate program in the Henry Samueli School of Engineering and Applied Science
3. Students must maintain a minimum cumulative grade-point average of 3.5 in the Ph.D. program.

4. Students must complete at least the following requirements: (a) four formal graduate courses selected in consultation with the faculty adviser, (b) Electrical Engineering 297, (c) one technical communications course such as Electrical Engineering 295, (d) no 500-level courses, other seminar courses, nor Electrical Engineering 296 or 375 may be applied toward the course requirements, (e) pass the Ph.D. preliminary examination which is administered by the department and takes place once every year. In case of failure, students may be reexamined only once with consent of the departmental graduate adviser, (f) pass the University Oral Qualifying Examination which is administered by the doctoral committee, (g) complete a Ph.D. dissertation, (h) defend the Ph.D. dissertation in a public seminar with the doctoral committee.

5. A formal graduate course is defined as any 200-level course, excluding seminar or tutorial courses. Formal graduate courses taken to meet the M.S. degree requirements may not be applied toward the Ph.D. course requirements.

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 completed, 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, 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 only once 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.

**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 only once 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.

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**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 Development of Emerging Storage Systems (CoDESS)**

The Center for Development of Emerging Storage Systems (CoDESS) has a dual mission: to push the frontiers of modern data storage systems through an integrated research program and to create a highly-trained workforce of graduate students. Current research thrusts include information and coding theory for ultra-reliable data storage systems, data reduction algorithms and communication methods for cloud storage, enabling technologies for future recording paradigms and storage devices, and resource-efficient signal processing techniques and architecture optimization.

**Center for Engineering Economics, Learning, and Networks**

The Center for Engineering Economics, Learning, and Networks will develop a new wave of ideas, technologies, networks, and systems that change the ways in which people (and devices) interact, communicate, collaborate, learn, teach, and discover. The center brings together an interdisciplinary group of researchers from diverse disciplines—including computer science, electrical engineering, economics, and mathematics—with diverse interests spanning microeconomics, machine learning, multiagent systems, artificial intelligence, optimization, and physical and social networks, all sharing a
common passion: developing rigorous theoretical foundations to shape the design of future generations of networks and systems for interaction.

**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 LSIs 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 (CERC–LA)**

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 (NCSCI), 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 164DA 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, ultrastable lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:sapphire, and visible and infrared 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. 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 multichannel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing.

The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, 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 llinpack performance of 68.1 TF (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 crystallization study, (5) thin film and characterization equipment, (6) deep-level transient spectroscopy instruments, (7) computerized capacitance-voltage and other characterization equipment, including dopant density profiling systems, (8) low-temperature facilities for material and device physics studies in cryogenic temperatures, (9) optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, (10) characterization equipment for high-speed devices, including (11) high magnetic field facilities for magnetotransport measurement of heterostructures. The laboratory facilities are available to faculty, staff, and graduate students for their research.

**Wireless Health Institute (WHI)**

Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical Engineering), Majid Sarrafzadeh, Ph.D. (Computer Science), Co-Directors

WHI is leading initiatives in health care solutions in the fields of disease diagnosis, neurological rehabilitation, optimization of clinical outcomes for many disease conditions, geriatric care, and many others. WHI also promotes this new field in the international community through the founding and organization of the leading Wireless Health conference series, Wireless Health 2010, 2011, 2012, 2013, and 2014.

WHI technology always serves the clinician community through jointly developed innovations and clinical trial validation. Each WHI program is focused on large-scale product delivery in cooperation with manufacturing partners. WHI collaborator is the UCLA schools of Medicine, Nursing, and Engineering and Applied Sciences; Clinical Translational Science Institute for medical research; Ronald Reagan UCLA Medical Center; and faculty from many departments across UCLA. WHI education programs span high school, undergraduate, and graduate students, and provide training in end-to-end product development and delivery for WHI program managers.

WHI develops innovative, wearable biomedical monitoring systems that collect, integrate, process, analyze, communicate, and present information so that individuals become engaged and empowered in their own health care, improve their quality of life, and reduce burdens on caregivers. WHI products appear in diverse areas including motion sensing, wound care, orthopaedics, digestive health and process monitoring, advancing athletic performance, and many others. Clinical trials validating WHI technology are underway at 10 institutions. WHI products developed by the UCLA team are now in the marketplace in the U.S. and Europe. Physicians, nurses, therapists, other providers, and families can apply these technologies in hospital and community practices. Academic and industry groups can leverage the organization of WHI to rapidly develop products in complete-care programs and validate in trials. WHI welcomes new team members and continuously forms new collaborations with colleagues and organizations in medical science and health care delivery.

**Multidisciplinary Research Facilities**

The department is also associated with several multidisciplinary research centers including

- California NanoSystems Institute (CNSI)
- Center for Embedded Networking 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
- WIN Institute of Neurotechnologies (WiNS)

**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)
- Algorithmic Research on Network Information Laboratory (Fragouli)
- Antenna Research, Analysis, and Measurement Laboratory (Rahmat-Samii)
- Autonomous Intelligent Networked Systems (Rubin)
- BioPhotonics Laboratory (Ozcan)
- CMOS Research Laboratory (Woo)
- Communication Circuits Laboratory (Razzavi)
- 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 (Josh)
- Microwave Electronics Laboratory (Itoh)
- Millimeter Wave and Optoelectronics Laboratory (Fettner)
- Nanoelectronics Research Center (Candler)
- Nanostructure Devices and Technology Laboratory (Chui)
- Nanosystems Computer-Aided Design Laboratory (Gupta)
- Networked and Embedded Systems Laboratory (Srivastava)
- Networks, Economics, Communication Systems, Informatics, and Multimedia Research Lab Focus (van der Schaar)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonsvitch)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Electronics Laboratory (Stafsudd)
- Robust Information Systems Laboratory (Dolecek)
- Sensors and Technology Laboratory (Candler)
- Speech Processing and Auditory Perception Laboratory (Alwan)
- Terahertz Devices and Intersubband Nanostructures Group (Williams)
- Terahertz Electronics Laboratory (Jaranli)
- Wireless Integrated Systems Research Group (Daneshrad)
Faculty Areas of Thesis Guidance

Professors
Abeer A.H. Alwan, Ph.D. (MIT, 1992) Speech processing, acoustic properties of sound 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 U., Taiwan, 1979) High-speed semiconductor (GaAs, InP, and Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuits
Panagiotis D. Christofides, Ph.D. (U. Minnesota, 1996) Process modeling, dynamics and control, computational and applied mathematics
Jason (Jingsheng) Cong, Ph.D. (U. 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 nano-technologies
Babak Daneshrad, Ph.D. (UCLA, 1993) Digital VLSI circuits: wireless communication systems, high-performance communications integrated circuits for wireless applications
Suhas Digavgi, Ph.D. (Stanford, 1989) Wireless communication, information theory, wireless networks, data compression, signal processing
Warren S. Grunfeldt, M.D., FACS (Columbia, 1980) Development of lasers for medical applications, minimally invasive surgery, magnetic resonance-guided interventional procedures, laser lithotripsy, microendoscopy, spectroscopy, photodynamic therapy (PDT), optical technology, biologic feedback control mechanisms
Lei He, Ph.D. (UCLA, 1999) Computer-aided design of VLSI circuits and systems, coarse-grain programmable systems and field programmable gate arrays (FPGA), high-performance interconnect modeling and design, power-efficient computer architectures and systems, numerical and combinatorial optimization
Diana L. Huffaker, Ph.D. (U. Minnesota, 1996) Solid-state nanotechnology, MMWR optoelectronic devices, solar cells, Si photonics, novel materials
Tatsuo Itoh, Ph.D. (U. Illinois Urbana, 1969) Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas; photonic bandgap structures and metamaterial 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
William J. Kaiser, Ph.D. (Wayne State, 1983) Research and development of new microsensor and microinstrumentation technology for industry, science, and biomedical applications; development and applications of new atomic-resolution scanning probe microscopy methods for microresearch
Alan Laub, Ph.D. (U. 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 sensing of clouds and aerosols and climate/clouds-aerosols research
Jia-Ming Liu, Ph.D. (Harvard, 1982) Laser and charged particle beam-plasma interactions; advanced accelerator concepts, advanced light sources, laser-fusion, high-energy density science, high-performance computing, plasma physics
Aydogan Ozcan, Ph.D. (McMaster U., Canada, 1988) Biomaging, nano-photronics, nonlinear optics
Gregory J. Pottie, Ph.D. (McMaster U., Canada, 1988) Communication systems and theory with applications to wireless sensor networks
Yahya Rahmat-Samii, Ph.D. (U. Illinois, 1975) Satellite communications antennas, personal communication antennas including human interactions, antennas for remote sensing and radio astronomy, applications of advanced numerical and genetic optimization techniques in electromagnetics, frequency selective surfaces and photonic band gap structures, novel integrated and fractal antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory
Behzad Razavi, Ph.D. (Stanford, 1992) Analog, RF, and mixed-signal integrated circuit design, digital-standard RF transceivers, phase-locked systems and frequency synthesizers, A/D and D/A converters, high-speed data communication circuits
Iwani P. Roychowdhury, Ph.D. (Stanford, 1989) Models of computation including parallel and distributed processing systems, quantum computation and information processing, circuits and computing paradigms for nano-electronics and molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory
Izhak Rubin, Ph.D. (Princeton, 1970) Telecommunications and computer communications systems and networks, mobile wireless networks, multimedia IP networks, AUI/UGV-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering
Henry Samueli, Ph.D. (UCLA, 1980) VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design
Ali H. Sayed, Ph.D. (Stanford, 1992) Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems
Stefano Soatto, Ph.D. (Caltech, 1996) Computer vision, sensor 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
Mans 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
Pablo 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
Lieve Vandenberghe, Ph.D. (Katholieke U. Leuven, Belgium, 1992) Optimization in engineering and applications in systems and control, circuit design, and signal processing
Mihaiela van der Schaar, Ph.D. (Eindhoven U. Technology, Netherlands, 2001) Multimedia processing and compression, multimedia 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, MBE 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
C.-K. Ken Yang, Ph.D. (Stanford, 1998) High-performance VLSI design, digital and mixed-signal circuit design
Kung Yao, Ph.D. (Princeton, 1965) Communication theory, signal and array processing, sensor system, wireless communication systems, VLSI and systolic algorithms

Professors Emeriti
*AV. Balakrishnan, Ph.D. (USC, 1954) Control and communications, flight systems applications
Francis F. Chen, Ph.D. (Harvard, 1954) Radio frequency plasma sources and diagnostics for semiconductor processing

* Also Professor Emeritus of Mathematics

Electrical Engineering / 83
Harold R. Fetterman, Ph.D. (Cornell, 1968)
Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state millimeter wave structures and systems, biomedical applications of lasers
Stephan E. Jacobsen, Ph.D. (UC Berkeley, 1968)
Operations research, mathematical programming, nonconvex programming, applications of mathematical programming to engineering and economics, control 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 stabilizability, errors in dynamic systems, signal analysis, wavelets, 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
*C. Kumar N. Patel, Ph.D. (Stanford, 1961)
Quantum electronics; nonlinear optics; photo-acoustics in gases, liquids, and solids; ultra-low level detectors for trace gases; chemical and toxic gas sensors
Frederick W. Schott, Ph.D. (Stanford, 1949)
Electromagnetics, applied electromagnetics
Gabor C. Temes, Ph.D. (U. Ottawa, 1961)
Analog MOS integrated circuits, signal processing, analog and digital filters
Chand R. Viswanathan, Ph.D. (UCLA, 1964)
Semiconductor electronics: VLSI devices and technology, thin oxides; reliability and failure physics of MOS devices; process-induced damage, low-frequency noise
Control systems, modeling and control of nonlinear distributed-parameter systems with applications to micro-opto-electromechanical systems, micro and nano manipulator systems, coordination and control of multiple microspacecraft in formation
†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
Active circuits, electronic systems
Alan N. Willison, Jr., Ph.D. (Syracuse, 1967)
Theory and application of digital signal processing including VLSI implementations, digital filter design, nonlinear circuit theory
Associate Professors
Daniela Cabríc, Ph.D. (U.C Berkeley, 2007)
Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and digital communication algorithms, parallel analysis and experiments on embedded system platforms
Chi On Chui, Ph.D. (Stanford, 2004)
Nanoelectronic and optoelectronic devices and technology, heterostructure semiconductor devices, monolithic integration of hetero- neous technology, exploratory nanotechnology
Christina Fragouli, Ph.D. (UCLA, 2000)
Network information flow theory and algorithms network coding and applications 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
Mona Jarrahi, Ph.D. (Stanford, 2007)
Radio frequency (RF), microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonics and optoelectronics
Sudhakar Pamarti, Ph.D. (UC San Diego, 2003)
Mixed-signal systems, signal processing and communication theory
Yuanxun Ethan Wang, Ph.D. (U. 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
Ultrafast optics, quantum optics, precision measurements in mesoscopic optoelectronics devices, microwave photonics and ultrafast spectroscopy of nanoscale materials
Assistant Professors
Robert N. Candler, Ph.D. (Stanford, 2006)
MEMS and nanoscale devices, fundamental limitations of sensors, packaging, biological and chemical sensing
Lara Docek, 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
Adjunct Professors
Ezio Biglieri, Dr. Ing. (Politecnico di Torino, Italy, 1989)
Digital communication, wireless channels, modulation, error-control coding, signal processing in telecommunications
Darush Divsalar, Ph.D. (UCLA, 1978)
Information theory; communication theory, bandwidth-efficient combined coding modulation techniques, spread spectrum systems and mutual user interference cancellation for CDMA, turbo codes, binary and nonbinary LDPC codes, and channel coding; 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
Yi-Chi Shih, Ph.D. (U. Texas Austin, 1989)
Microwaves and communications, and passive devices, characterization and modeling, integrated circuits, components and subsystems for sensors and communications applications
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 Yablonovitch, Ph.D. (Harvard, 1972)
Optoelectronics, high-speed optical communications, photonic integrated circuits, photonic crystals, plasmonic optics and plasmonic circuits, quantum computing and communication
Adjunct Associate Professor
Kaiseki Goda, Ph.D. (MIT, 2007)
Biophotonics, imaging, fiber-optic communications
Adjunct Assistant Professors
Pedram Khalili Amiri, Ph.D. (Delft U. Technology, Netherlands, 2008)
Nanoelectronics, spintronics, nano-magnetism and nonvolatile memory and logic
Jin Hyung Lee, Ph.D. (Stanford, 2004)
Advanced imaging techniques for biomedical applications; neurosciences and neural engineering; magnetic resonance imaging (MRI); development of novel image contrast strategies; alternate image acquisition, reconstruction, and processing
Shervin Moloudi, Ph.D. (UCLA, 2008)
Telecommunication analog and high-frequency circuit design
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, Fermi energies, and concepts of electrons in solids. Discussion of electrical properties of semiconductors, leading to operation of junction devices.
Letter grading.
Mr. Jalali, Mr. Williams (F,Sp)
3. Introduction to Electrical Engineering. (3) Lecture, two hours; laboratory, two hours; 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.
Mr. Pottie, Mr. Stafudd (F,Sp)
10. Circuit Theory I. (4) Lecture, four hours, discussion, one hour; outside study, seven hours. Requisite: sites 3 course 3 (or Computer Science 1 or Materials Science 10), Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced), Mathematics 33B, Introduction to linear circuit theory. Resistive circuits, capacitors, inductors and ideal transformers, Kirchhoff's laws, node and loop analysis, first-order circuits, second-order circuits, Thévenin and Norton theorem, sinusoidal steady state. Letter grading.
Mr. Gupta, Mr. Razavi (F,W)
11L. Circuits Laboratory I. (1) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced co-requisite: course 10. Experiments with basic circuits containing resistors, capacitors, inductors, and transformers. Ohm's law voltage and current division, Thévenin and Norton equivalent circuits, superposition, transient and steady state analysis. Letter grading.
Mr. Gupta, Mr. Parnami (FW)
Mr. Srivastava (F,Sp)
19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.
99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Enforced for lower division students under guidance of faculty
Upper Division Courses

100. Electrical and Electronic Circuits. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 33A, Physics 1C. Not open for credit to students with credit for course 110. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state circuit behavior, semiconductor devices, small signal models, and operational amplifiers. Letter grading.

Mr. Razavi (F,W)

101A. Electromagnetism. (4) Formerly numbered 110L. 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 charts, vectors and phasors, vector addition, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading.

Mr. Razavi, Mr. Williams (W,S)

101B. Electromagnetic Waves. (4) Formerly numbered 161L. Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Time-varying fields and Maxwell equations, reflection and transmission of waves, waveguide media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and antennas. Letter grading.

Mr. Y.E. Wang (W,S)


Mr. Vandenberghe (F,W)

110. Circuit Theory II. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: courses 10, 102. Enforced corequisites: course 110L. 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. Razavi (F,S)

110L. Circuit Measurements Laboratory. (2) Laboratory, four hours; outside study, two hours. Requisites: course 100 or 110. Experiments with basic circuits containing resistors, capacitors, inductors, and op-amps. Ohm’s law voltage and current division, Thévenin and Norton equivalent circuits, superposition, transient and steady state analysis, and frequency response principles. Letter grading.

Mr. Razavi (F,W)

111L. Circuits Laboratory II. (1) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced requisites: courses 10, 111L. Enforced corequisite: course 101B. Laboratory experiments with electrical circuits containing resistors, capacitors, inductors, transformers, and op-amps. Steady state power analysis, frequency response principles, op-amp-based circuit simulations, and current feedback network principles. Letter grading.

Mr. Razavi (F,W)

113. Digital Signal Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 102. Relationship between continuous-time and discrete-time signals, Z-transform, Discrete Fourier transform, Fast Fourier transform. Structures for digital filtering. Introduction to digital filter design techniques. Ms. van der Schaar (F,S)

113DA-113DB. Digital Signal Processing Design. (4-4) Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments involve design, compilation, debugging, 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. 113DA. (Formerly numbered 113D.) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 110L. Project, grading, and given only on completion of course 113DB. 113DB. Laboratory, four hours; outside study, eight hours. Enforced requisites: courses 113, 113DA. Completion of projects begun in course 113DA. Letter grading.

Mr. Daneshbad (113DA in F,W; 113DB in W,S)

114. Speech and Image Processing Systems Design. (4) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Enforced requisite: course 110. Review of techniques for image processing systems for speech production, analysis, and modeling in first half of course; design techniques for image enhancement, filtering, and transformation. Lectures supplemented by laboratory implementation of speech and image processing tasks. Letter grading.

Ms. Alwan, Mr. Villasenor (Sp)

115A. Analog Electronic Circuits I. (4) Lecture, four hours; discussion, one hour; laboratory, two hours; outside study, seven hours. Enforced requisite: course 110. Review of techniques for analog electronic circuits. Analysis and design of single-stage amplifiers, DC biasing circuits, small-signal response. Operational amplifier systems. Letter grading.

Mr. Daneshbad (F,S)

115AL. Analog Electronics Laboratory I. (2) Laboratory, four hours; outside study, two hours. Enforced requisites: courses 110L or 111L, 115A. Experimental determination of device characteristics, resistive diode circuits, single-stage amplifiers, compound transistor stages, effect of feedback 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. Abidi (F,S)

115B. Analog Electronic Circuits II. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 115A. Analysis and design of differential and noninverting and CMOS and bipolar circuits, current and voltage feedback amplifiers, Miller’s capacitor and operational amplifiers, and operational amplifier circuits. Introduction to hands-on design experience based on individual student hardware design and implementation platforms. Letter grading.

Mr. Abidi (W)

115BL. Analog Electronics Laboratory II. (4) Laboratory, four hours; outside study, eight hours. Enforced requisite: course 115B. Recommended corequisite: course 115D. Study of high-frequency effects in operational amplifiers and design of high-frequency characteristics. Modern mirrors and active loads. Frequency response of amplifiers. Feedback and its properties. Stability issues and frequency compensation. Letter grading.

Mr. Razavi (W)

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. Transistor-level digital circuits and design. Modern logic families (static CMOS, pass-transistor, dynamic logic), integrated circuit (IC) layout, digital circuit design, logic gate-level design, flip-flops/latches, counters, etc., computer-aided simulation of digital circuits. Letter grading.

Ms. Cabric, Mr. Yang (F,S)


Mr. Abidi (M)

M116C. Computer Systems Architecture I. (4) (Same as Computer Science M151B.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M16 or Computer Science M51A. Computer Science M51A. Recommended: course M16L or Computer Science M512A. Computer system organization and design, implementation of CPU datapath and control, instruction set architecture, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading.

Mr. Gupta (W,S)

M116L. Introductory Digital Design Laboratory. (2) (Same as Computer Science M512A.) Laboratory, four hours; outside study, two hours. Enforced requisite: course M16 or Computer Science M51A. Hands-on design, implementation, and debugging of digital logic circuits, use of computer-aided design tools for schematic capture and simulation, implementation of complex circuits used in computer-aided design, introduction to computer programming tools. Letter grading.

Mr. He (F,W)

M117. Computer Networks: Physical Layer. (4) (Same as Computer Science M117.) Lecture, two hours; discussion, two 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. Focus on wireless and 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., Blue-tooth). 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. Dzhindzhi (F,W)

121B. Principles of Semiconductor Device Design. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 121A. Introduction to principles of operation of bipolar and MOS transistors, equivalent circuits, high-frequency behavior, voltage limitations. Letter grading.

Mr. Chiu, Mr. Hsiao (W)

121DA-121DB. Semiconductor Processing and Device Design. (4-4) Design fabrication and characterization of p-n junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Introduction to CAD tools used in integrated circuit processing and device design. Device structure optimization tool based on MEDICI; process integration tool based on SUPREM. Course familiarizes students with those tools. Using CAD tools, CMOS process integration to be designed. 121DA. (Formerly numbered 121L,) Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisite: course 121B. In progress grading (credit to be given only on completion of course 121DB). 121DB. (Formerly numbered 129D,) Lecture, two hours; laboratory, two hours; outside study, six hours. Enforced requisites: courses 121B, 121DA. Letter grading.

Mr. Chiu (121DA in W; 121DB in S)

122L. Semiconductor Devices Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, two hours. Enforced requisite: courses 2, 121B (may be taken concurrently). Design fabrication and characterization of p-n junction and transistors. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Letter grading. Mr. Candler
123A. Fundamentals of Solid-State I. (4) Lecture, three hours; outside study, one hour, seven hours. Enforced requisite: course 2 or Physics 1C. Limited to junior/senior engineering majors. Fundamentals of solid-state, introduction to quantum mechanics applicable to solid-state devices. Electrical, magnetic, and superconducting properties. Letter grading. Ms. Huffaker (F)

123B. Fundamentals of Solid-State II. (4) Lecture, three hours; outside study, one hour, seven hours. Enforced requisite: course 123A. Discussion of solid-state properties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading. Ms. Huffaker (Sp)

125. Principles of Nanoelectronics. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Requisite: Physics 1C. Introduction to fundamentals of nanoscale devices. Overview and application of nanoscale phenomena and devices. Letter grading. Mr. K-L. Wang (W)

131A. Probability and Statistics. (4) Lecture, four hours; discussion, one hour; outside study, 10 hours. Requisite: course 102 (enforced), Mathematics 32B, 33B. Introduction to basic concepts of probability, including mathematical expectation, random variables, distribution functions, and densities, moments, characteristic functions, and limit theorems. Applications to communication, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading. Mr. Roychowdhury, 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 2014-15)


133A. Mathematics of Design. (4) (Formerly numbered 103) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A, and Civil Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20. Emphasis on numerical computation analysis; analytic formulations versus numerical solutions; floating-point representations and rounding errors. Review of MATLAB; mathematical software. Linear equations; bisection; boundary value problems; iterative methods for solving linear equations; conditioning and stability; complexity, Interpolation and approximation; splines. Zeros and roots of nonlinear equations; polynomial (QR) factorization; statistical interpretation. Numerical optimization; Newton method; nonlinear least squares. Numerical quadrature. Solving ordinary differential equations. Eigenvalues and eigenvectors of matrices using the QR algorithm; statistical applications. Letter grading. Mr. Vandenberge (FsP)

133B. Simulation, Optimization, and Data Analysis. (4) (Formerly numbered 136) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 133A. Simulation of dynamical systems. Algorithms for ordinary differential and difference equations. Fourier analysis; fast Fourier transform. Random number generators. Simulation of stochastic systems, Monte Carlo methods. Constrained optimization; applications of optimization to engineering design, modeling, and data analysis. Introduction to data mining and machine learning. Algorithms and complexity. Integration of mathematical software in applications. Letter grading. Mr. Vandenberge (Sp)


142. Space-Time 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. Tabuada (W)

151MO. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) Same as Bioengineering CM150 and Aerospace Engineering CM180L. Lecture, four hours; discussion, one hour; outside study, seven hours. Required: 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 variety of MEMS, including microstructures and microelectromechanical systems. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM250A. Letter grading. Mr. Candler (F)

150DL. Photonic Sensor Design Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, eight hours. Limited to seniors. Multidisciplinary course with lectures and laboratory exercises on optical sensors. Fundamentals of intensity and interference-based transducers, polarimeters, multiplexing and sensor networks, physical and bio-medical sensors. Design and implementation of optical gyroscope, computer interfacing, and signal processing. Letter grading. (Not offered 2014-15)

151MO. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM150 and Aerospace Engineering CM180L). Lecture, one hour; laboratory, four hours; outside study, one hour. Requisites: course CM50, Chemistry 20A, 20L, Physics 1A, 1B, 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 and microelectromechanical systems. Students go through process of fabricating MEMS devices. Concurrently scheduled with course CM250A. Letter grading. Mr. Li (F)

170B. Photonic Devices and Circuits. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: 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, optical wave propagation and modes, optical interferometers and resonators, optical coupling and modulation, optical absorption and emission, principles of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (W)

170C. Photonic Sensors and Solar Cells. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 170A. Coverage of core knowledge of practical photonic devices and circuits. Topics include optical waveguides, optical fibers, optical couplers, optical modulators, lasers and light-emitting diodes, optical detectors, and integrated photonic devices and circuits. Letter grading. Mr. Li (W)

183A. Introductory Microwave Circuits. (4) Lecture, four hours; discussion. Required: course 102B, Electromagnetics, seven hours. Enforced requisite: course 101B. Transmission lines description of waveguides, impedance matching techniques, power dividers, directional couplers, medium devices, transistor amplifier design. Letter grading. Mr. Ihof (F)

183C. Introduction to Microwave Systems. (4) Lecture, four hours; outside study, eight 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 microwave devices. Letter grading. Mr. Ihof, Mr. Jalali (Not offered 2014-15)

164DA-164DB. Radio Frequency Design Project I, II. (4-4) (Formerly numbered 164D.) Lecture, one hour; laboratory; three hours; outside study, eight hours. Enforced requisite: course 115B. Course 164D is enforced requisite to senior Electrical Engineering majors. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience. Design of radio frequency transceivers and their building blocks according to given specifications or in form of open-ended problems. Introduction to advanced topics related to projects through lecture and laboratories. Creation by students of end-to-end systems in application context, managing trade-offs across subsystems while meeting constraints and optimizing metrics related to cost, performance, ease of use, manufacturability, testability, and other real-world issues. Oral and written presentations of project results required. In Progress (164DA) and letter (164DB) grading. Mr. Ihof, Mr. Razavi (164DA in W); Mr. Chang (164DB in Sp)

164L. Microwave Wireless Laboratory. (2) Lecture, one hour; laboratory; three hours; outside study, three hours. Enforced requisite: course 101B. Measurement techniques and instrument use of passive microwave components; cavity resonators, waveguides, waveometers, slotted lines, directional couplers. Design, fabrication, and characterization of microwave circuits in microstrip and coaxial systems. Letter grading. Mr. Ihof (F)

170A. Principles of Photonics. (4) Lecture, four hours; recitation, one hour; 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, optical wave propagation and modes, optical interferometers and resonators, optical coupling and modulation, optical absorption and emission, principles of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (W)

170B. Photonic Devices and Circuits. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 170A. Coverage of core knowledge of practical photonic devices and circuits. Topics include optical waveguides, optical fibers, optical couplers, optical modulators, lasers and light-emitting diodes, optical detectors, and integrated photonic devices and circuits. Letter grading. Mr. Liu (W)

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 device physics subjected to vacuum, field effects, and conversion of light to electrical energy in solar cells. Introduction to radiometry, semiconductor pho-
161D. Robotic Systems Design. (4) Lecture, two hours; outside study, six hours. Requisites: courses M16, 110L, M116L (or Computer Science M152A), Computer Science 31, 33. Recommended: courses 113, 141, Computer Science 170A or 170B. Design and implementation of computer-based embedded hardware, software, mechanical subsystems, and fundamental algorithms for sensing and control to expose students to basic concepts in robotics, computer graphics, computer vision, and art. Letter closely tied to design laboratory where students work in teams to construct series of subsystems leading to final project. Letter grading.

CM182. Science, Technology, and Public Policy. (4) Lecture, four hours. Requisites: course 115C. Detailed study of ethical, social, economic, political, and technological aspects. Consideration of selection of critical policy issues, each of which has substantial ethical, social, economic, political, scientific, and technological aspects. Concurrently scheduled with course CM262. Letter grading.

M136DA-136DB. Design of Digital Hardware I, II (4-4) Limited to senior Electrical Engineering majors. Design of specialized hardware functions in system-on-chip application processor context with integration of diverse processing technologies such as processors, memories, logic circuits, and hardware accelerators. Design of logic gates, their size and voltage optimization for energy-delay trade-offs, operation of clocked storage elements and their timing parameters, timing analysis of digital logic, architecture parallelism and time multiplexing, clock and power. Introduction to advanced project-related topics. Open-ended projects vary annually. Students create hardware accelerator engines for various applications. 136DA. Lecture, one hour; laboratory, four hours; outside study, seven hours. Enforced requisite: courses M16 or Computer Science M51, 116L. Course 115B in Progress grading (credit to be given only on completion of course 136DB). 136DB. Laboratory, four hours; outside study, eight hours. Enforced requisite: course 115C. Letter grading.

174. Semiconductor Optoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101A. Study of basic properties of semiconductors, photodetectors, and photoactive solar cells of various types and materials. Letter grading.

M. Williams (Sp)

170L. Laser Laboratory. (4) (Formerly numbered 172L.) Lecture, four hours; outside study, eight hours. Enrolled students must also complete core 101A. Properties of lasers, including saturation, gain, mode structure. Laser applications, including optics, modulation, communication, holography, and interferometry. Letter grading.

Mr. Steelap (M171L. Data Communication Systems Laboratory. (2 to 4) (Same as Computer Science M171L) Laboratory, four to eight hours; outside study, two to four hours. Recommended preparation: course M171; not open to students who have credit for course M117. Interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and display signals in relevant laboratory setups. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modern and terminal characteristics, and interfaces. Letter grading.

Mr. Dzhanidze (W,Sp)

173DA-173DB. Photonics and Communication Design. (4-4) Lecture, four hours; laboratory, four hours; outside study, eight hours. Introduction to measurement of basic photonic devices, including LEDs, lasers, detectors, and amplifiers; fiber-optic fundamentals and measurement of fiber systems. Modulation techniques, including A.M., F.M., phase and suppressed carrier methods. Possible projects include lasers, optical communication, and biomedical imaging and sensing. 173DA. (Formerly numbered 173D.) Enforced requisite: course 101A. Recommended: course 170A or Bioengineering C170. Choice of project preliminary design. In Progress grading in combination of networked embedded systems design. Laboratory 173DB. Enforced requisite: courses 101A, 173DA. Finalization of design and testing of projects begun in course 173DA. Letter grading.

M. Williams (W,Sp)

174. Semiconductor Optoelectronics. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisite: course 101A. Study of different types of optical systems and their physics background. Examination of their roles in current and projected biomedical applications. Specific capabilities of phototonic to be related to each example. Letter grading.

Mr. Ozcan (W)

180DA-180DB. Systems Design. (4-4) Limited to senior Electrical Engineering majors. Advanced systems design integrating communications, control, and signal processing subsystems. Introduction to advanced topics related to projects through lecture and laboratories. Open-ended projects vary each offering. Students create high-performance designs that manage trade-offs among subsystem components. Enforced requisite: performance of required course 180BD. Performance, processes of design, and other contexts. Oral and written presentation of project results. 180DA. (Formerly numbered 180AI.) Lecture, two hours; laboratory, four hours; outside study, six hours. In Progress grading (credit to be given only on completion of course 180BD). 180DB. Laboratory, four hours; outside study, eight hours. Enforced requisite: course 180BD. Course 180A is enrolled for students who have been advanced to the status of junior or senior. Designed for students who are part of research group. Discussion of re- search methods and current literature in field. May be repeated for credit. Letter grading.

Mr. Kaiser, Mr. Pottie (180DA in F,W; 180DB in W,Sp)

Graduate Courses

201A. VLSI Design Automation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 115C. Fundamentals of design automation of VLSI circuits and systems, including introduction to circuit and system modeling, simulation, and parameter tools for performing gate arrays and multicomputer systems; high-level synthesis, logic synthesis, and technology mapping; physical design; and testing and verification. Letter grading.

Mr. Gupta (W)


Mr. He (Not offered 2014-15)

201D. Design in Nanoscale Technologies. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 115C. Challenges of digital circuit design and layout in deeply scaled technologies, with focus on design-manufacturing interactions. Summary of large-scale digital design flow; basic manufacturing flow; lithographic patterning, resolution enhancement, and mask preparation; yield and variation modeling; circuit reliability and aging issues; design rules and their origins; layout design for manufacturing; test structures and process control; circuit architecture methods for variability mitigation. Letter grading.

Mr. Gupta (Sp)

M202A. Embedded Systems. (4) (Same as Computer Science M213A.) Lecture, four hours; outside study, eight hours. Designed for graduate computer science and electrical engineering students. Methodologies and technologies for design of embedded systems. Topics include hardware and software platforms for embedded systems, techniques for modeling and specification of system behavior, software organization, real-time operating system scheduling, real-time communication and packet scheduling, low-power batteries and power management design, timing synchronization, fault tolerance and debugging, and techniques for hardware and software architecture optimization. Theoretical foundations are presented as well as practical design methods. Letter grading.

Mr. Srivastava (F)

M202B. Energy-Aware Computing and Cyber-Physical Systems. (4) (Same as Computer Science M213B.) Lecture, four hours; outside study, eight hours. Requisite: course M16 or Computer Science M51A. Recommended: course M116C or Computer Science M151B, and Computer Science 111. System-level management and cross-layer methods for power and energy consumption in computing and communication at various scales ranging across embedded, mobile, personal, enterprise, and data-center scale. Computing, networking, sensing, and control technologies and algorithms for improving energy sustainability in human-computer-physical systems. Topics include modeling of energy consumption, energy sources, and energy storage; dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware scheduling; low-power protocols; battery modeling and management; thermal management; sensing of power consumption. Letter grading.

Mr. Srivastava (Sp)

202C. Networked Embedded Systems Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Designed for graduate computer science and electrical engineering students. Training in combination of networked embedded systems design combining embedded hardware platform, embedded operating system, and hardware/software in
20AS. Seminar: Circuits and Embedded Systems. (4) Lecture, four hours; discussion, two hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of circuits and embedded systems, such as digital/analog, mixed-signal, and radio frequency integrated circuits (RF ICs); electronic design automation; wireless communication circuits and systems; embedded processor architectures; embedded software; distributed sensor and actuator networks; robotics; and embedded security. May be repeated for credit with topic change. S/U grading.

Mr. Gupta (W)

210A. Adaptation and Learning. (4) Lecture, four hours; outside study, eight hours. Preparation: prior training in probability theory, random processes, and linear algebra. Recommended requisites: courses 205A, 241A. Mean-square-error estimation and filters, least-squares estimation and filters, steepest-descent algorithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance, algorithms for adaptation and learning, adaptive filters, learning and classification, optimization. Letter grading. Mr. Sayed (W)


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


212B. Multirate Systems and Filter Banks. (4) Lecture, three hours; outside study, nine hours. Preparation: course 212A. Fundamentals of multirate systems; polyphase representation; multirate implementation; applications of multirate systems; maximally decimated filter banks; perfect reconstruction systems; paraunitary filter banks; wavelet transforms and its relation to multirate filter banks. Letter grading. Mr. Pamarti (Not offered 2014-15)

213A. Advanced Digital Signal Processing Circuit Design. (4) Lecture, three hours; outside study, nine hours. Preparation: 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. Mr. Wilson (Not offered 2014-15)

214A. Digital Speech Processing. (4) Same as Bioengineering M214A. Lecture, three hours; laboratory, two hours; outside study, seven hours. Preparation: course 113. Theory and applications of digital processing of speech signals. Mathematical models of human speech perception: mechatronic 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. Mr. Markovic (Sp)


215B. Advanced Digital Integrated Circuits. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Preparation: courses 115C, M216A. Analysis and design of analog integrated circuits. MOS and bipolar device structure models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, offset and distortion, sampling devices and discrete-time circuits, bandgap references. Letter grading. Mr. Razavi (Sp)


215E. Signaling and Synchronization. (4) Lecture, four hours; outside study, eight hours. Preparation: courses 215A, M216A. Analysis and design of circuits for synchronization and digital communication. Use of digital and analog design techniques to improve data rate of electronics between functional blocks, chips, and systems. Advanced coding methods, channel estimation, and design for clock generation, and high-performance wire-line transmitters, receivers, and timing recovery circuits. Letter grading. Mr. Pamarti (Sp)

216A. Design of VLSI Circuits and Systems. (4) Same as Computer Science M298A. Lecture, four hours; discussion, one hour; laboratory, four hours; outside study, three hours. Preparation: courses M16 or Computer Science M51A, and 115A. Recommended: course 115C, LS/LSI design and application. Introduction in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. 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 architecture design and optimization within block-recursive description that can be mapped to hardware. Fundamental concepts from digital signal processing (DSP) theory, architecture, and circuit design applied to complex DSP algorithms in emerging applications for personal communications and healthcare. Letter grading. Mr. Markovic (Sp)

216C. LSI in Computer System Design. (4) Same as Computer Science M298C. Lecture, four hours; laboratory, four hours; outside study, four hours. Preparation: course M216A. LSI/LSI design
M217. Biomedical Imaging. (4) (Same as Bioengineering 217.) Lecture, four hours; outside study, nine hours. Prerequisite: course 114 or 211A. Optical imaging modalities in biotechnology. Other imaging modalities discussed briefly for comparison purposes. Letter grading. Mr. Ozcan (W)

218. Network Economics and Game Theory. (4) Lecture, four hours; outside study, eight hours. Discussion of how different cooperative and noncooperative game-theoretical models can be applied to network design problems. Various mechanisms for learning equilibria, fictitious play, regret-minimizing, and mixed-strategy equilibria. Tutorials on tutorial topics and in research topic in their dissertation area. May be repeated for credit. S/U grading. (Not offered 2014-15)

219A. Physics of Semiconductor Devices I. (4) Lecture, four hours; outside study, eight hours. Principles and design considerations of junction devices. Letter grading. Mr. Wang, Mr. Wu (F)

219B. 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. Wu (W)

221A. Microcircuit Semiconductor Devices. (4) Lecture, four hours; outside study, eight hours. Principles and design considerations of microcircuit solid-state devices: Schottky barrier mixer diodes, IMPATT diodes, transferred electron devices, tunnel diodes, microstrip transistors. Letter grading. Ms. Wu (Not offered 2014-15)

222. Integrated Circuits Fabrication Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 2. Principles of integrated circuits fabrication technology, including photolithography, etch, diffusion, ion-implantation, deposition, lithography, and metallization, with stress on advanced process simulation tools. Letter grading. Mr. Chui (Not offered 2014-15)

223. Solid-State Electronics I. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 124, 276. Energy band theory, electronic band structure of various elementary, compound, and alloy semiconductors, defects in semiconductors. Recombination mechanisms, transport properties. Letter grading. Mr. Chui (F)

224. Solid-State Electronics II. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Techniques to solve Boltzmann transport equation, various scattering mechanisms in semiconductors, high frequency semiconductor devices, Monte Carlo method in transport. Optical properties. Letter grading.

225. Physics of Semiconductor Nanodevices and Devices. (4) Lecture, four hours; outside study, eight hours. Requisite: course 223. Mathematical methods for calculating electronic and optical properties of semiconductor structures. Quantum size effects and low-dimensional systems. Application to semiconductor nanodevices, such as nanowires, nanotubes, carbon nanotubes and carbon nanofibers. Letter grading. Ms. Hufaker (Sp, alternate years)

229. Seminar: Research 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 semiconductor devices, optical and microweave semiconductor devices, nonlinear optics, and electron emission. Letter grading. (Not offered 2014-15)

229S. Advanced Electrical Engineering Seminar. (2) Seminar, two hours; outside study, six hours. Preparation: successful completion of Ph.D. major field examination or permission of instructor. Topics include research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on tutorial topic and on research topic in their dissertation area. May be repeated for credit. S/U grading. (Not offered 2014-15)

230A. Estimation and Detection in Communication and Radar Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 131A. Applications of optimization 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) estimation and detection algorithms; detection under ML, Neyman, and Neyman-Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Letter grading. (Not offered 2014-15)

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 and quantization; receiver susceptibility in Gaussian noise; comparison of digital modulation methods; synchronization and adaptive equalization; applications to modern communication systems. Letter grading. Mr. Yao (Sp)


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 estimation, AR and ARMA; systolic applications. Letter grading. (Not offered 2014-15)

231A. Information Theory: Channel and Source Coding. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Fundamental limits on compression and transmission of information. Topics include limits and algorithms for lossless data compression, channel capacity, rate versus distortion in lossy compression, and information theory for multiple users. Letter grading. Mr. Diggavi (F)

231E. Channel Coding Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131A. Introduction to modern error control codes and decoding algorithms. Topics include block codes, convolutional codes, trellis codes, and turbo codes. Letter grading. Mr. Wieser (Sp)

232A. Stochastic Modeling with Applications to Telecommunication Systems. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Introduction to stochastic processes as applied to study of telecommunication systems; renewal theory; discrete-time Markov chains; continuous-time Markov jump processes. Applications to traffic and queueing analysis of basic telecommunication system models. Letter grading. Mr. Rubin (F)

232B. Telecommunication Switching and Queueing Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232A. Queue modeling and analysis with applications to space-time digital switching systems and to integrated-service telecommunication systems. Fundamentals of traffic engineering and queueing theory, waiting time, busy period, blocking, and stochastic process analysis for Markovian and non-Markovian models. Letter grading. Mr. Rubin (Not offered 2014-15)


232D. Telecommunication Networks and Multiple Access Communications. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Performance analysis and design of telecommunications networks and multiple-access communication systems. Topics include architectures, multiplexing and multiple-access, message delays, error/flow control, satellite communication. Applications to local-area, packet-radio, local-distribution, computer and satellite communication networks. Letter grading. Mr. Rubin (W)


233. Wireless Communication Networks and Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 232B. Basic concepts of wireless communication and computer networks. Topics include wireless communication channels, coding schemes, propagation characteristics, multipath fading, and medium access control for wireless networks. Letter grading. Mr. Pottie (Not offered 2014-15)

236A. Linear Programming. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Mathematics 115A or equivalent knowledge of linear algebra. Basic graduate course in linear optimization. Geometry of linear programming. Duality. Simplex method. Interior-point methods. Decomposition and large-scale linear programming. Quadratic programming and complementary pivot theory. Engineering applications. Introduction to integer linear programming and computational complexity theory. Letter grading. Mr. Vanderberghe (F)


M237. Dynamic Programming. (4) Same as Mechanical and Aerospace Engineering M276.) Lecture, four hours; outside study, eight hours. Recommended requisite: course 232A or 236A or 236B. Introduction to mathematical analysis of sequential decision processes. Finite horizon models in both deterministic and stochastic cases. Finite-state infinite horizon models. Methods of solution. Examples from inventory theory, finance, optimal control and estimation. Markov decision processes, combination of optimal control, optimization, communications. Letter grading. (Not offered 2014-15)


241C. Stochastic Control. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 240B, 241B. Linear quadratic Gaussian theory of optimal feedback control of stochastic systems; discrete-time state-space models; sigma algebra equivalence and separation principle; dynamic programming; compensator design for time invariant systems; feed-forward control and servomechanisms, extensions to nonlinear systems; applications to interconnection guidance, gust alleviation. Letter grading. (Not offered 2014-15)


243. Robust and Optimal Control by Convex Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: course 240A. Multivariable robust control, including H2 and H∞ optimal control and robust performance analysis and synthesis against structured uncertainty. Emphasis on convex methods for analysis and design, in particular linear matrix inequality (LMI) approach to control. Letter grading. (Not offered 2014-15)

M248S. Seminar: Systems, Dynamics, and Control Topics. (2) Same as Chemical Engineering M297 and Mechanical and Aerospace Engineering M299A.) Seminar, two hours; outside study, six hours. 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. Mr. Candler (Sp)

CM250A. Introduction to Micromachining and Microelectromechanical Systems (MEMS). (4) Same as Bioengineering M239A and Mechanical and Aerospace Engineering M239A.) Lecture, four hours; discussion, one hour; outside study, seven hours. 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 variety of MEMS, including microstructures, microsensors, and micro-actuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM150L. Letter grading. Mr. Candler (Sp)

CM250L. Introduction to Micromachining and Microelectromechanical Systems Laboratory. (2) Same as Bioengineering CM250L and Mechanical and Aerospace Engineering CM280L.) Lecture, one hour; laboratory, four hours; outside study, eight hours. Requisites: course CM250A, Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining technologies and microelectromechanical systems (MEMS) laboratory. MEMS devices are fabricated and tested. Micromachining and lithographic processes 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) Device Physics and Design. (4) Same as Bioengineering M252 and Mechanical and Aerospace Engineering M282.) Lecture, four hours; outside study, eight hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Desigining 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 M256 and Neuroscience M256.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 6B. 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, stimulus artifact removal), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading. Mr. Markovic (W)

M256A-M256B-M256C. Evaluation of Research in Neuroengineering. (4) Same as Bioengineering M256A-M256B-M256C 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. Enrolled students must complete course CM250A. Introduction to fundamental concepts and experiments of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembled) nanofabrication, nanofluidics, nanomaterials, nanoelectronics, and nanobio-detection technology. Introduction to new knowledge and techniques in nano areas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading. Mr. Chen (Not offered 2014-15)

260A. Advanced Engineering Electrodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 161, 162A. Advanced treatment of concepts in electrodynamics and their applications to modern engineering problems. Vector calculus in generalized coordinate system. Solutions of wave equation and special functions of wave propagation, reflection, and polarization. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, and sphere, including radar cross-section characterization. Green’s functions in electromagnetics and dyadic calculus. Letter grading. Mr. Rahmat-Samii (Fall)


261. Microwave and Millimeter Wave Circuits. (4) Lecture, four hours; outside study, eight hours. Requisite: course 163A. Rectangular and circular waveguides, microstrip, stripline, and dielectric waveguide distributed circuits, with applications in microwave and millimeter wave integrated circuits. Substrate materials, surface wave phenomena. Analytical methods for discontinuity effects. Design of passive microwave and millimeter wave circuits. Letter grading. Mr. Itoh (W)

262. Antenna Theory and Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 162A. Microstrip design, antenna synthesis, analysis, and self-phase modulation. Nonlinear photonic devices, such as photodiodes, self-phase modulation, and Brillouin scattering, field-induced index changes and Brillouin scattering, field-induced index changes. Compact range concepts. Microwave diode and transistor techniques. Compact range concepts. Microwave diode and transistor techniques. Modern satellite and ground antenna applications. Letter grading. Mr. Rahmat-Samii (Not offered 2014-15)


270. Applied Quantum Mechanics. (4) Lecture, four hours; outside study, eight hours. Preparation: modern physics (or course 123A), linear algebra, and ordinary differential equations courses. Principles of quantum mechanics for applications in lasers, solid-state physics, and nonlinear optics. Topics include eigenfunction expansions, observables, Schrödinger equation, uncertainty principle, central force problems, nonrelativistic approximation, molecular mechanics, density matrix formalism, and radiation theory. Letter grading. Mr. Stafsudd (F)

271. Classical Laser Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 172. Microscopic physical laser phenomena, including propagation of optical pulses using classical formalism. Letter grading. Mr. Joshi (W)


280A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydro-magnetic waves, drift waves. Rayleigh/Taylor/Kelvin/Helmholtz/Arnold-Sommerfeld instability. Applications to experiments in fully and partially ionized gases. Letter grading. Mr. Villasenor (W)

285A. Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Microwave propagation, plasma oscillations, ion acoustic waves, cyclotron waves, hydro-magnetic waves, drift waves. Rayleigh/Taylor/Kelvin/Helmholtz/Arnold-Sommerfeld instability. Applications to experiments in fully and partially ionized gases. Letter grading. Mr. Villasenor (W)

285B. Advanced Plasma Waves and Instabilities. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 101, and M185 or Physics M122. Interaction of intense electromagnetic waves with plasmas: waves in inhomogeneous and bounded plasmas, nonlinear wave coupling and damping, parametric instabilities, anomalous resistivity, shock waves, echoes, laser heating. Emphasis on experimental considerations and techniques. Letter grading. Mr. Joshi (F)

285C. Manufacturing Systems. (4) Lecture, four hours; outside study, eight hours. Modeling and analysis of manufacturing systems. Assembly and transfer-line systems, facility layout and design, Group technology and flexible manufacturing systems. Planning and scheduling. Task management, machine setup, and operation sequencing. Manufacturing system models, systems and manufacturing information systems. Social, economic, environmental, and regulatory issues. Letter grading. Mr. Tabuada (W)

357. Teaching Apprentice Practicum. (1 to 4) Seminar, three hours. Preparation: apprenticeship for personnel employment as teaching assistant, associate, or fellow. Teaching apprenticeship under active guidance of faculty mentor. Regular meetings, culminating report, and presentation required. Individual contract required; enrollment petitions available in Office of Graduate Student Affairs. S/U grading.

475C. Manufacturing Systems. (4) Lecture, four hours; outside study, eight hours. Modeling and analysis of manufacturing systems. Facility layout and design. Group technology and flexible manufacturing systems. Planning and scheduling. Task management, machine setup, and operation sequencing. Manufacturing system models, systems and manufacturing information systems. Social, economic, environmental, and regulatory issues. Letter grading. Mr. Tabuada (W)

475D. Directed Individual or Tutorial Studies. (2 to 12) Tutorial, to be arranged. Limited to graduate engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Studies. Supervised investigation of advanced technical problems. S/U grading.

475A. Preparation for M.S. Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate electrical engineering students. Preparation for M.S. comprehensive examination. S/U grading.

475B. Preparation for Ph.D. Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate electrical engineering students. S/U grading.

475C. Preparation for Ph.D. Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate electrical engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

Materials Science and Engineering

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Dwight C Streit, Ph.D., Chair
Mark S. Goorsky, Ph.D., Vice Chair
Suneel Kodambaka, Ph.D., Vice Chair

Professors
Russel E. Caflisch, Ph.D.
Gregory P. Carman, Ph.D.
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Yong Chen, Ph.D.
Bruce S. Dunn, Ph.D. (Nippon Sheet Glass Company Professor of Materials Science)
Nasr M. Ghoniem, Ph.D.
Mark S. Goorsky, Ph.D.
Vijay Gupta, Ph.D.
Robert F. Hicks, Ph.D.
Richard B. Kaner, Ph.D.
Ali Mosleh, Ph.D. (Evalyn Knight Professor of Engineering)
Vidvuds Ozolins, Ph.D.
Qibing Pei, Ph.D.
Dwight C. Streit, Ph.D.
Sarah H. Tolbert, Ph.D.
King-Ning Tu, Ph.D.
Kang L. Wang, Ph.D. (Raytheon Company Professor of Electrical Engineering)
Paul S. Weiss, Ph.D.
Benjamin M. Wu, D.D.S., Ph.D.
Ya-Hong Xie, Ph.D.
Jenn-Ming Yang, Ph.D.
Yang Yang, Ph.D. (Carol and Lawrence E. Tannas, Jr., Endowed Professor of Engineering)

Professors Emeriti
Alan J. Ardell, Ph.D.
David L. Douglass, Ph.D.
William Klement, Jr., Ph.D.
John D. Mackenzie, Ph.D. (Nippon Sheet Glass Company Professor Emeritus of Materials Science)
Kanji Ono, Ph.D.
Aly H. Shabaik, Ph.D.
George H. Sines, Ph.D.

Associate Professors
Yu Huang, Ph.D.
Ioanna Kakoulili, D.Phil.
Suneel Kodambaka, Ph.D.
Jaime Marian, Ph.D.

Adjunct Professor
Harry Patton Gillis, Ph.D.

Adjunct Associate Professors
Eric P. Bescher, Ph.D.
Kosmas Galatias, Ph.D.
Esther H. Lan, Ph.D.

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

Materials engineering builds on the foundation of materials science and is concerned with the design, fabrication, and optimal selection of engineering materials that must simultaneously fulfill dimensional, property, quality control, and economic requirements. The Department of Materials Science and Engineering 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.
The research efforts of professor Suneel Kodambaka's In situ Microscopy Lab are focused on synthesis and characterization of low-dimensional structures such as quantum dots, nanowires, and graphene thin films. Research students include (left to right) Dean Cheikh, Jeung Hun Park, Chilan Ngo, Filiberto Colon, and Yuya Murata.
Graduate Study
For information on graduate admission, see Graduate Programs, page 24.

The following introductory information is based on the 2014-15 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, 243A, 243C, 250B, 298.

As long as a majority of the courses taken are offered by the department, substitutions may be made with the consent of the departmental graduate adviser.

Undergraduate Courses. No lower division courses may be applied toward graduate degrees. In addition, the following upper division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 106A, 108, 199, Computer Science M152A, 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.

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 multi-layer) 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 kV), a field emission transmission electron microscope (200 kV), 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. Caflisch, 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 multifractals, magnetoelectrics and piezoelectric materials

Jane P. Chang, Ph.D. (MIT, 1998) Materials processing, gas phase and surface reaction, plasma enhanced chemistry, atomic layer 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 electrochemical materials, energy storage, sol-gel materials and chemistry

Nasr M. Ghoniem, Ph.D. (U. Wisconsin, 1977) Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ion, plasma, electronics, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

Mark S. Goorsky, Ph.D. (MIT, 1989) Electronic materials processing, strain relaxation in epitaxial semiconductor 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


Ali Mosleh, Ph.D. (UCLA, 1981) Reliability engineering, physics of failure modeling and system life prediction, resilient systems design, prognostics and health monitoring, hybrid systems simulation, theories and techniques for risk and safety analysis

Vidvuds Ozolins, Ph.D. (Kungliga Tekniska Högskolan, Sweden, 1998) Materials theories, computational materials design, materials for energy storage and generation, magnets and optical materials, thermoelectrics, mathematical models for atomic simulation and quantum mechanics, machine learning, knowledge extraction

Qibing Pei, Ph.D. (Chinese Academy of Sciences, China, 1990) Electroactive polymers through molecular design and nano-engineering for electronic devices and artificial muscles


Sarah H. Tolbert, Ph.D. (UC Berkeley, 1995) Self-organized nanostructured materials for energy storage, energy harvesting, nanomagnetics and nanoelectronics

King-Ning Tu, Ph.D. (Harvard, 1968) Kinetic processes in thin films, metal-silicon interfaces, electromigration, Pb-free interconnects, 3D IC packaging


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

Benjamin M. Wu, D.D.S., Ph.D. (MIT, 1997) Processing, characterization, and controlled delivery of biological molecules of bioerodible polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

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. (U. Delaware, 1986) Nanomechanical testing, nanostructured materials, ceramic and ceramic matrix composites, hybrid materials and composites, material synthesis and processing

Yang Yang, Ph.D. (U. Massachusetts Lowell, 1992) Organic and inorganic semiconductor materials and devices with emphasis on solution processes; fundamental understanding of material properties; optoelectronic devices (LEDs, PVs, TFT, 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 Klement, Jr., Ph.D. (Caltech, 1962) Phase transformations in solids, high-pressure effects on solids


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

Ally H. Shabaik, Ph.D. (UC Berkeley, 1966) Metal forming, metal cutting, mechanical properties, friction and wear, biomaterials, manufacturing processes

George H. Sines, Ph.D. (UCLA, 1953) Fracture of ceramics, fatigue of metals, carbon-carbon composites, failure analysis
types of materials used in engineering designs: metals, ceramics, glasses, and polymers, and the relationship between structure (crystals and microstructure) and properties of technological materials. Illustration of their fundamental differences and their applications in engineering. Letter grading.

Mr. Dunn (F, WS/Fs)

M105. Principles of Nanoscience and Nanotechnology. (4) (Same as Engineering M101.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, Physics 1C. Introduction to underlying science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena, characteristic of materials (typically with feature sizes below few hundred nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron 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)

110. Introduction to Materials Characterization A (Crystal Structure, Nanomaterials, and X-Ray Scattering). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 104. Modern methods of materials characterization: fundamentals of crystallography, 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.

Mr. Goorsky (F)

110L. Introduction to Materials Characterization A Laboratory. (2) Laboratory, four hours; outside study, two hours. Enforced requisites: course 104. Experimental techniques and analysis of materials through X-ray scattering techniques; powder method, crystal structure determination, high-resolution X-ray diffraction methods, and special projects. Letter grading.

Mr. Goorsky (F)

C111. Introduction to Materials Characterization B (Electron Microscopy). (4) (Formerly numbered 111.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Enforced requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials using electron microscopy; reciprocal lattice, electron diffraction, stereochemical projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflective mode, and analysis; electron optics of both instruments. Concurrently scheduled with course C211. Letter grading.

Mr. Kodambaka (F)


(Courses offered 2014-15)


Mr. Y. Yang (W)

121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 120. Structure and properties of elemental and compound semiconductors. Electrical and optical properties, defect chemistries, and doping. Electronic-transport analysis and characterization, including electrical, optical, and ion-beam techniques. Heterostructures, band-gap engineering, development of new materials for optoelectronic applications. Letter grading.

Ms. Huang (Sp)

121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Enforced requisites: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Mr. Goorsky (Sp)

122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 104. Description of basic semiconductor materials for device processing: preparation of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielectrics. Letter grading.

Mr. Goorsky (W)

130. Phase Relations in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 104, and Chemical Engineering 102A or Mechanical and Aerospace Engineering 105A. Summary of thermodynamic laws, equilibrium criteria, solution thermodynamic mass-action law, binary and ternary phase diagrams, glass transitions. Letter grading.

Mr. Xie (F)

131. Diffusion and Diffusion-Controlled Reactions. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 130. Diffusion in metals and ionic solids, nucleation and growth theory; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of intermediate phases, gas-solid reactions, design of oxidation-resistant alloys, recrystallization, and grain growth. Letter grading.

Mr. Tu (W)

131L. Diffusion and Diffusion-Controlled Reactions Laboratory. (2) Laboratory, two hours; outside study, four hours. Enforced requisites: course 131. Physical metallurgy of steels, lightweight alloys (Al and Ti), and superalloys. Strengthening mechanisms, microstructural control methods for strength and toughness improvement. Grain boundary segregation. Letter grading.

Mr. J.-M. Yang (Sp)

C133. Ancient and Historic Metals: Technology, Microstructure, and Corrosion. (4) Lecture, two hours; laboratory, 90 minutes. Processes of extraction, alloying, surface patination, metallic coatings, corrosion, and characterization of ancient and historic metals. Extensive laboratory work in preparation and examination of metallic samples under microscope, as well as lectures on technology of metallic wroks of art. Practical instruction in metallographic microscopy. Exploration of phase and stability diagrams of common alloying systems and environments and analytical techniques appropriate for the study of metallographic and histochemical artifacts. Concurrently scheduled with course CM233. Letter grading.

(Courses offered 2014-15)

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 metals, nonferrous alloys, polymeric, ceramic, and composite materials,
141L. Computer Methods and Instrumentation in Materials Science. (2) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Junior/senior Materials Science and Engineering majors, interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading. Mr. Goorsky (W)

143A. Mechanical Behavior of Materials. (4) Lecture, four hours; 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, dislocation structures, 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). Methods of characterizing mechanical behavior of various materials; plastic and elastic deformation, fracture toughness, fatigue, and creep. Letter grading.

Mr. Ono (Not offered 2014-15)

150. Introduction to Polymers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, polymer structure and conformation, solution properties, elastomers, adhesives. Letter grading. Mr. Pei (W)

151. Structure and Properties of Composite Materials. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Preparation: at least two courses from 132, 143A, 143B. Mechanical behavior of composite materials with fiber and particulate reinforcement. Properties of fiber, matrix, and interfaces. Selection of macrostructures and material systems. Letter grading. Mr. J-M. Yang (Sp)

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 as used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in ceramic engineering. Letter grading. Mr. Dunn (W)


Mr. Dunn (Not offered 2014-15)

161L. Laboratory in Ceramics. (2) Laboratory, four hours. Requisite: course 160. Recommended corequisite: course 161. Processing of common ceramics and glassy materials; type of specific properties through process control for engineering applications. Quantitative characterization and selection of raw materials. Slip casting and extrusion of clay bodies. Sintering, glazing, melting and finishing. 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 microelectronics; thick film and thin film resistors, capacitors, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics and magnetic properties; dielectric ceramics and electronic devices; optical wave guide applications and designs. Letter grading. Mr. Dunn (Not offered 2014-15)

170. Engaging Elements of Communication: Oral Communication. (4) Lecture, one hour; outside study, four hours. Comprehensive oral presentation and communication skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentations for wide range of audiences. Learning environment is highly supportive and interactive. Creative and develop and greatly expand effectiveness of their communication and presentation skills. Letter grading.

Mr. Xie (Not offered 2014-15)

171. Engaging Elements of Communication: Writing for Technical Community. (4) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive technical writing skills on subjects specific to field of materials science and engineering. Students write review term paper in selected subject field of materials science and engineering from given set of journal publications. Instruction leads students through several crucial steps, including brainstroming, choosing title, coming up with outline, concise writing of abstract, conclusion, and final polishing. Other subjects include writing style, word choices, and grammar. Letter grading.

Mr. Xie (Not offered 2014-15)

CM180. Introduction to Biomaterials. (4) Same as Biotechnology CM178. Lecture, three hours; discussion, one hour; outside study, seven hours. Requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and replacement of various tiss
ues. 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 (Not offered 2014-15)

188. Special Courses in Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are interested in research and engineering for undergraduate students taught on experimental and/or research basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Not offered 2014-15)

194. Research Group Seminars: Materials Science and Engineering. (2) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are interested in research and engineering for undergraduate students taught on experimental and/or research basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Not offered 2014-15)

199. Directed Research in Materials Science and Engineering. (1-9) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. Occasional field trips may be arranged. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.

Mr. Goorsky (W)  
Mr. Y. Yang (F)


Mr. Chyu (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 (X rays, X rays, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of plastic deformation, solid-state transformations, arrangements of atoms in liquids and amorphous solids. Letter grading. Mr. Goorsky (Sp, odd years)

C211. Introduction to Materials Characterization B (Electronics Microscopy). (4) Lecture numbered 211L. Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; electron microscopy; reciprocal lattice, electron diffraction, spectroscopic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflection microscope use of micro-optics for both instruments. Concurrently scheduled with course C111. Letter grading. Mr. Kodambaka (W)

CM212. Cultural Materials Science II: Characterization Methods in Conservation of Materials. (4) (Same as Conservation M210.) Lecture, four hours. Preparation: general chemistry, inorganic and organic chemistry, materials science. Principles and methods of materials characterization in conservation: optical and electron microscopy, X-ray and electron spectroscopy, X-ray diffraction, infrared spectroscopy, reflectance spectroscopy and multispectral imaging spectroscopy, chromatic design, archaeo-
tological and ethnographic materials characterization procedures. Concurrently scheduled with course C112. Letter grading. (Not offered 2014-15)


M216. Science of Conservation Materials and Methods I. (4) (Same as Conservation M216.) Seminar, one hour; laboratory, three hours. Recommended requisite: course 104. Introduction to physical, chemical, and mechanical properties of conservation materials (employed for preservation of archaeological and cultural objects) and their aging characteristics. Science and application methods of traditional organic and inorganic systems and introduction of novel technology based on biominalization processes and nanostructured materials. Letter grading.

221. Science of Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Study of major physical and chemical principles affecting properties and performance of semiconductor materials. Topics include bonding, carrier statistics, band-gap engineering, optical and transport properties, novel materials systems, and characterization. Letter grading. Mr. Goorsky (Sp)


Mr. Goorsky (W)

223. Materials Science of Thin Films. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 131, Fabrication, structure, and property correlations of thin films used in microelectronics for data and information processing. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading. Mr. Tu
224. Deposition Technologies and Their Applications. (4) Lecture; four outside study, eight hours. Examination of physics behind majority of modern thin film deposition technologies based on vapor phase transport. Basic vacuum technology and gas phase deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition techniques. Mr. Xie

225. Materials Science of Surfaces. (4) Lecture, four hours; outside study, eight hours. Requisites: course 120, Chemistry 113A. Introduction to atomic and electronic structure of surfaces. Survey of methods for determining the composition and structure of surfaces and near-surface layers of solid-state materials. Emphasis on scanning probe microscopy. Auger electron spectroscopy, X-ray photoelectron spectroscopy, ultraviolet photoelectron spectroscopy, secondary ion mass spectrometry, ion scattering spectroscopy, and Rutherford backscattering spectroscopy. Applications in microelectronics, optoelectronics, metallurgy, polymers, biological and bio-compatible materials, and material analysis. Mr. Gillis, Mr. Goorsky (W)

226. Si-CMOS Technology: Selected Topics in Materials Science. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Recommended preparation: Electrical Engineering 221B. Requisites: courses 130, 131, 200, 221, 222. Selected topics in materials science from modern Si-CMOS technology, including technological challenges in high k/metal gate stacks, strained Si FETs, SOI and three-dimensional MOSFETs, device modeling, and fabrication techniques. Mr. Xie

CM233. Ancient and Historic Metals: Technology, Microstructure, and Corrosion. (4) (Same as Conservation M246.) Lecture, two hours; laboratory, 90 minutes. Introduction to the properties, formation, and corrosion behavior of ancient and historic metal objects. Emphasis on laboratory work in preparation and examination of metallic samples under microscope, as well as lectures on technology of metallic works of art. Practical instruction in metallurgical microscopy. Exploration of phase and stability diagrams of common alloy systems and environmental and analytical techniques appropriate for examination and characterization of metallic artifacts. Concurrently scheduled with course C133. Letter grading. (Not offered 2014-15)

243A. Fracture of Structural Materials. (4) Lecture, four hours; outside study, four hours. Requisite: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture. Fracture mechanics, dislocation models, fatigue, fracture in reactive environments, alloy development, fracture-safe design. Letter grading. Mr. J.-M. Yang (W, even years)

243C. Dislocations and Strengthening Mechanisms in Solids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143A. Elastic and plastic behavior of crystals, geometry, mechanics, and interaction of dislocations, mechanisms of yielding in work hardening, and other strengthening mechanisms. Letter grading. Mr. Xie (F, odd years)

246B. Structure and Properties of Glass. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143A. Structure of amorphous solids and glasses. Composition of glass formation and the structure of glass structure. Mechanical, electrical, and optical properties of glass and relationship to structure. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 160. Principles governing electronic properties of ceramic single crystals and glasses and their optical and microstructure analysis on these properties. Electronic conduction, ferroelectricity, and photochemistry. Magnetic ceramics. In-frared, visible, and ultraviolet transmission. Unique application of ceramics. Letter grading. Mr. Dunn (Sp, even years)

247. Nanoscale Materials: Challenges and Opportunities. (4) Lecture, four hours; discussion, eight hours. Limited to graduate students. Literature studies of up-to-date subjects and their potential applications, including nanoscale materials and biomaterials. Letter grading. Ms. Huang (W)

248. Materials and Physics of Solar Cells. (4) Lecture, four hours. Comprehensive introduction to materials and physics of photovoltaic cell, covering basic physics of semiconductors in photovoltaic devices, physical models of cell operation, characteristics and design of common types of solar cells, and approaches to increasing solar cell efficiency. Recent progress in solar cells, such as organic solar cell, thin-film solar cells, and multiple junction solar cells provided to increase student knowledge. Tour of research laboratory included. Letter grading. Mr. Y. Yang (Sp)


251. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: organic molecules, synthetic polymers, and biomolecules and biomaterials. Extensive description and discussion of structure-property relationship, spectroscopic and experimental techniques, and preparation methods for various soft materials. Letter grading. Mr. Pei (F)

252. Organic Polymer Electronic Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to organic electronic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers; highly doped, highly conducting polymers; applications as processable metals and in various optical, electrical, and electrochemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes and thin-film transistors. Introduction to emerging field of organic electronics. 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 show how these methods can be used to study interesting phenomena in materials science. Hands-on computer experiments. Letter grading. Mr. Ozolins (F)


272. Theory of Nanomaterials. (4) Lecture, four hours; discussion, eight hours. Recommended requisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding of basic principles that distinguish nanostructures (with sizes below 100 nm) from more common microstructured materials. Explanation of new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics. Topics include structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assembly on surfaces and in liquid solutions, mechanical properties of nanomaterials, molecular electronics, and proposed realizations of quantum computing. Discussion of current and future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. Ozolins (F)

CM280. Introduction to Biomaterials. (4) (Same as Bioengineering CM278.) 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 effects, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (Not offered 2014-15)

282. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Researchers from leading research institutions around world deliver lectures on advanced research topics in materials science and engineering. Students or groups present summary previews of topics prior to lecture. Class discussions follow each presentation. May be repeated for credit. S/U grading. Mr. J.-M. Yang

292. Seminar: Advanced Topics in Materials Science and Engineering. (2) Seminar; two hours; outside study, four hours. Advanced study and analysis of current topics in materials science and engineering. Discussion of current research and literature in research specialty of faculty members teaching course. May be repeated for credit. S/U grading.

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

375. Teaching Apprentice Practicum. (1 to 4 Seminar, to be arranged. Preparation: apprentice permit and employment as teaching assistant, teaching fellow, 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)

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

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


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

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Gregory P. Carman, Ph.D.
Jiun-Shyan Chen, Ph.D.
Yong Chen, Ph.D.
Vijay K. Dhir, Ph.D., Dean
Rajit Gadh, Ph.D.
Nasr M. Ghozien, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor of Aeronautics)
Dennis W. Hong, Ph.D.
Tetsuya Iwasaki, Ph.D.
Y. Sungtaek Ju, Ph.D.
Ann R. Karagozian, Ph.D.
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J. John Kim, Ph.D. (Rockwell Collins Professor of Engineering)
Adrienne G. Lavine, Ph.D.
Xiaochun Li, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
Kuo-Nan Liou, Ph.D.
Christopher S. Lynch, Ph.D.
Ajit K. Mal, Ph.D.
Robert T. M'Closkey, Ph.D.
Laurent G. Pilon, Ph.D.
Jacob Rosen, Ph.D.
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Tsu-Chin Tsao, Ph.D.
Xiaolin Zhong, Ph.D.

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Owen I. Smith, Ph.D.
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.
Daniel C.H. Yang, Ph.D.

Associate Professors
Pei-Yu Chiong, Ph.D.
Jeff D. Eldredge, Ph.D.
H. Pirouz Kavehpour, Ph.D.
William S. Klug, Ph.D.
Veronica J. Santos, Ph.D.
Richard E. Wirz, Ph.D.

Assistant Professors
Jonathan B. Hopkins, Ph.D.
Yongjie Hu, Ph.D.

Lecturers
Ravneesh C. Amar, Ph.D.
Amiya K. Chatterjee, Ph.D.
Robert J. Kinsey, Ph.D.
Carl F. Ruoff, Ph.D.
Judy I. Shane, M.S.
Damian M. Toohy, M.S.

Adjunct Professors
Dan M. Goebel, Ph.D.
Leslie M. Lackman, Ph.D.
Wilbur J. Marner, Ph.D.
Neil B. Morley, Ph.D.
Robert S. Shaerfe, Ph.D.
Neil G. Siegel, Ph.D.
Ronaldo Szilard, Ph.D.

Adjunct Associate Professor
Gopinath R. Warrier, Ph.D.

Adjunct Assistant Professor
Abdon E. Sepulveda, 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 microelectromechanical 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 aeroelasticity, dynamics, control and guidance, propulsion, and energy conversion.

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, C150P, C150R 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 94, 105D, 131A, C132A, 133A, 135, 136, C137, CM140, 150C, C150G, C150R (unless taken as a required course), 153A, 155, 161A (unless taken as a required course), 161B, 161C, 161D, 162A, 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 20 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; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Mechanical and Aerospace Engineering M20 or Computer Science 31; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 107, 150A, 150B, C150P, C150R 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 94, 105D, 131A, C132A, 133A, 135, 136, C137, CM140, 150C, C150G, C150R (unless taken as a required course), 153A, 155, 161A (unless taken as a required course), 161B, 161C, 161D, 162A, 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 20 or http://www.registrar.ucla.edu/ge/.

Professor Dennis Hong and CHARLI (Cognitive Humanoid Autonomous Robot with Learning Intelligence), the humanoid robot, enjoy ice cream together. CHARLI is the first American full-size, two-legged, walking humanoid robot.
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, M116L, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering
Breath 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) 155 or 169A or 169A, (4) 161A or 171A.

Graduate-Level Requirement. Students are required to take at least one course from the following: Mechanical and Aerospace Engineering 250C, 250D, 250F, 254A, 255B, 256F, 263B, 269D, or 271B. The remaining courses can be taken to gain depth in one or more of the several specialty areas covering the existing major fields in the department.

Mechanical Engineering
Breath 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 at least three faculty members, with at least two members from within the department, and chaired by the academic advisor, is established to administer the examination. Students may, in consultation with their advisor 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:


Upper Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 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, 294, 295B, C296A, 297B, 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 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 may 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 often 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, bio fluid 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, bio fluid 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 aeroelasticity, fluid structure interaction, computational transonic aeroelasticity, 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 tune hood, wafer saw, wire bonder, electroplating setup including vacuum capability, various microscopes including fluorescent and 3D scanning, various probe stations including RF capability, vibration-isolation and optical tables, environmental chambers, drop dispensing system, various instruments (e.g., impedance analyzer), and full video imaging capability. It is used for MEMS and nano research, and complements the HSSEAS Nanoelectronics Research Facility, the 8,500-square-foot, class 100/1000 clean room where most micromachining steps are carried out.

Microsciences Laboratory

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

Multifunctional Composites Laboratory

The Multifunctional Composites Laboratory provides equipment necessary to develop multifunctional nanocomposites and explore their applications by integrating technologies involving composites, nanomaterials, information, functional materials, biomimetics, and concurrent engineering. Some of the equipment in the laboratory includes an autoclave, a filament wind road, a resin transfer molding machine, a waterjet cutting machine, a stereo lithography machine, a laminated object manufacturing machine, a coordinate measuring machine, a field emission scanning electron microscope, a scanning probe microscope, an FTIR, a rheometer, a thermal analysis system, an RCL analyzer, a microdielectric analyzer, an X-ray radiography machine, and a variety of mechanical testing machines.

Multiscale Thermosciences Laboratory

The Multiscale Thermosciences Laboratory 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 3 x 3-foot Subsonic Wind Tunnel is used for research on unsteady aerodynamics on oscillating airfoils and instruction.

Thin Films, Interfaces, Composites, Characterization Laboratory

The Thin Films, Interfaces, Composites, Characterization Laboratory consists of a Nd:YAG laser of 1 Joule capacity with three ns pulse widths, a state-of-the-art optical interferometer including an ultra high-speed digitizer, sputter deposition chamber, 56 Kip-capacity servohydraulic biaxial test frame, walk-in freezer, polishing and imaging equipment for microstructural characterization for measurement and control study of thin film interface strength, NDE using laser ultrasound, de-icing of structural surfaces, and characterization of composites under multi-axial stress state.

Faculty Areas of Thesis Guidance

Professors

Mohamed A. Abdou, Ph.D. (U. Wisconsin, 1973) Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermomechanics; thermal hydraulics; fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-matter interactions; blankets and high heat flux components; experiments; modeling and analysis

Oddvar O. Bendiksen, Ph.D. (UCLA, 1980) Classical and computational aerelasticity, structural dynamics and unsteady aerodynamics

Gregory P. Carman, Ph.D. (Virginia Tech, 1991) Electromagnetoelasticity models, fatigue characterization of piezoelectric ceramics, magneto-
strictive composites, characterizing shape memory alloys, flexible sensors, design of damage detection systems, micromechanical analysis of composite materials, experimentally evaluating damage in composites

Y. Sungtaek Ju, Ph.D. (Stanford, 1999)
Tetsuya Iwasaki, Ph.D. (Purdue, 1993)
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Nasr M. Ghoniem, Ph.D. (U. Wisconsin, 1977)
Vijay K. Dhir, Ph.D. (U. Kentucky, 1972)
Yong Chen, Ph.D. (UC Berkeley, 1996)

Jiun-Shyan (J-S) Chen, Ph.D. (Northwestern U., 1972)

Two-phase heat transfer, boiling and condensation, thermal hydrualics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling

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

Nasr M. Ghoniem, Ph.D. (U. Wisconsin, 1977)
Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, ions, plasma, electrons, and neutrons), material processing by plasma and beam sources, physics and mechanics of material defects, fusion energy

James S. Gibson, Ph.D. (U. Texas Austin, 1975)
Control and identification of dynamical systems; optimal and adaptive control of distributed systems, including flexible structures and fluid flows; adaptive filtering, identification, and noise cancellation

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular and phenomonic microelectromechanical systems (MEMS), bionano technologies, biomolecular sensor arrays, control of cellular complex systems, rapid search of combinatorial medicines

Dennis W. Hong, Ph.D. (Purdue, 2002)
Analysis and visualization of contact force solution space for multimodal mobile robots

Tetsuya Iwasaki, Ph.D. (Purdue, 1993)
Dynamical systems, robust and optimal controls, nonlinear oscillators, resonance entrainment, modeling and analysis of neuronal control circuits for animal locomotion, central pattern generators, body-fluid interaction during undulatory and oscillatory swimming

Y. Sungtaek Ju, Ph.D. (Stanford, 1999)
Heat transfer, thermodynamics, microelectromechanical and nanoelectromechanical systems (MEMS/NEMS), magnetism, nano-technology

Ann R. Karagozian, Ph.D. (Caltech, 1982)
Fluid mechanics and combustion with applications to improved engine efficiency, reduced emissions, alternative fuels, and advanced high-speed air breathing and rocket propulsion systems

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)

J. John Kim, Ph.D. (Stanford, 1978)
Turbulence, numerical simulation of turbulent and transitional flows, application of control theories to flow control

Adrienne Lavine, Ph.D. (UC Berkeley, 1964)
Heat transfer: turbulent behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection

Xiaolun Li, Ph.D. (Stanford, 2001)
Embedded sensors and manufacturing

Kuo-Nan Liou, Ph.D. (New York U., 1970)
Radiative transfer and satellite remote sensing with application to clouds and aerosols in the earth’s atmosphere

Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1990)
Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensor and actuator applications, fracture mechanics and failure analysis

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

Robert T. McLaughlin, Ph.D. (Caltech, 1995)
Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation

Laurent G. Plion, Ph.D. (Purdue, 2002)
Interfacial athermal phenomena, radiation transfer, materials synthesis, multi-phase flow, heterogeneous media

Jacob Rosen, Ph.D. (Tel Aviv U., Israel, 1997)
Natural integration of a human arm/powered exoskeleton

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

Tsu-Chin Tsao, Ph.D. (UC Berkeley, 1989)
Modeling and control of dynamic systems with applications in mechanical systems, manufacturing processes, automotive systems, and energy systems, digital control, repetitive and learning control, adaptive and optimal control, mechatronics

Xiaolin Zhong, Ph.D. (Stanford, 1991)
Computational fluid dynamics, hypersonic flow, rarefied gas dynamics, numerical simulation of transient hypersonic flow with nonequilibrium real gas effects, instability of hypersonic boundary layers

Professors Emeriti

Ivan Catton, Ph.D. (UCLA, 1966)
Heat transfer and fluid mechanics, transport phenomena in porous media, nucleate heat transfer and thermal relaxation, natural and forced convection, thermal/hydraulic stability, turbulence

Aerodynamics of helicopters and fixed-wing aircraft, structural dynamics of rotating systems, rotor dynamics, unsteady aerodynamics, active control of structural dynamics, structural optimization with aeroelastic constraints

H. Thomas Hahn, Ph.D. (Pennsylvania State, 1968)
Numerical simulations of fluid dynamics, biologically inspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vorticity-based numerical methods, simulations of biomedical flows

H. Prouz 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-heats, microfluidics, soft-matter physics

Computational structural and solid mechanics, finite element methods, computational biomechanics, nanomechanics of biological systems

Veronica J. Santos, Ph.D. (Cornell, 2007)
Bayesian approach to biomechanical modeling, treatise on human thumb

Richard E. Witz, Ph.D. (Caltech, 2005)
Space and plasma propulsion, partially ionized plasma discharges, behavior of miniature plasma devices, spacecraft and space mission design, wind energy, solar thermal energy

Assistant Professors

Jonathan B. Hopkins, Ph.D. (MIT, 2010)
Design and manufacturing of microstructural architectures, flexure systems, and compliant mechanisms; screw theory kinematics; precision machine design; novel micro- and nano-fabrication processes; MEMS

Yongjie Hu, Ph.D. (Harvard, 2010)
Nanowire platform for fundamental physics and applications in nanoelectronics and quantum devices
Upper Division Courses


102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A, Physics 1A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in two and three dimensions. Impulse-momentum and work-energy relationships. Applications. Letter grading.

103. Elementary Fluid Mechanics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 32B, 33A, Physics 1B. Introductory course dealing with application of principles of mechanics to flow of compressible and incompressible fluids. Letter grading.


131A. Intermediate Heat Transfer. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 105D, 205A. Principles of heat transfer by conduction, convection, and radiation. From analysis to applications. Letter grading.

132A. Mass Transfer. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 105D, 205A. Applications of thermodynamic principles to engineering processes. Fluid and heat transfer, mass transfer, chemical reactions, and chemical reaction engineering. Letter grading.

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 103, 105A. Engineering applications in thermal and power systems. Rankine cycle and other energy conversion systems. Introduction to nuclear power generation. Letter grading.

134. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 105A. 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, air and water pollution, global warming. Letter grading.

C137. Design and Analysis of Smart Grids. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 232A. Introduction to smart grid systems. Demand response; transactive/price-based load control; home-area network; smart energy profile; advanced metering infrastructure; renewable energy integration; solar and wind generation intermittency and correction; microgrids, grid stability, energy storage and electric vehicles; monitoring, distribution, and transmission grids; control of smart grid; sensors, control, and communication; wireless, electric, and powerline communications for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational awareness, phase angle measurement, and control. Letter grading.


Mr. Eldredge, Mr. Taciorgul (F,Sp)

94. Introduction to Computer-Aided Design and Drafting. (4) Lecture, two hours; laboratory, four hours. Fundamentals of two- and three-dimensional modeling on computer-aided design and drafting systems. Students use one or more online computer systems to design and display various objects. Letter grading.

Mr. Ghad, Mr. Li (F,Sp)

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

Lower Division Courses


Ms. Lavine (Not offered 2014-15)

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.

M20. Introduction to Computer Programming with MATLAB. (4) (Same as Civil Engineering M20.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mathematics 33A. Fundamen-
CM140. Introduction to Biomechanics. (4) Same as Biology 140. Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 101, 102, and 156A or 166A. Introduction to mechanical functions of human body; design, function, and response to optimization solutions, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM114D. Letter grading.  
Mr. Gupta (W)

Mr. Eldredge, Ms. Karagozian (F, W)

Mr. Zhong (Sp)

Mr. Mal (F, Sp)

156B. Mechanical Design I. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 155A. Analysis of machinery design, power transmission shafting. Design project involving computer-aided design (CAD) and finite element analysis (FEA) modeling. Lecture, four hours; discussion, two hours; outside study, six hours. Letter grading.  
Mr. Ghoniem (F)

157. Basic Mechanical Engineering Laboratory. (4) Laboratory, four hours; outside study, four hours. Enforced requisites: courses 101, 102, 103A, 105A, 156A. Not open to students with credit for course 157A, 157S. Basic Aerospace Engineering Laboratory. (4) Laboratory, five hours; outside study, four hours. Enforced requisites: courses 101, 102, 103A, 105A, 156A. Electrical Engineering 100. Recommended: course 15. Measurements of basic physical quantities in fluid mechanics, thermodynamics, and structures. Operation of primary transducers, computer-aided data acquisition, signal processing, and data analysis. Performance of experiments to enhance understanding of basic physical principles and characteristics of structure and apply knowledge to aerospace engineering. Letter grading.  
Mr. Kavehpour (Sp)

157S. Basic Aerospace Engineering Laboratory. (4) Laboratory, five hours; outside study, four hours. Enforced requisites: courses 101, 102, 103A, 105A, 156A. Electrical Engineering 100. Recommended: course 15. Measurements of basic physical quantities in fluid mechanics, thermodynamics, and structures. Operation of primary transducers, computer-aided data acquisition, signal processing, and data analysis. Performance of experiments to enhance understanding of basic physical principles and characteristics of structure and apply knowledge to aerospace engineering. Letter grading.  
Mr. Ju (W, Sp)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 102. Recommended: course 102A. Spaceflight, including two-body and three-body problem, Kepler laws, and Keplerian orbits. Letter grading.
186C. Design of Composite Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 156A or 166A. History of composites, stress-strain relations for composite materials, bending and extension of symmetric laminates, design of composite structures, and design studies, buckling of composite components, non-symmetric laminates, micromechanics of composites. Letter grading. Mr. Carman (W)

M185. Introduction to Finite Element Methods. (4) (Same as Civil Engineering 156C, Mechanical Engineering 161B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 156A or 166A or Civil Engineering 130. Introduction to basic concepts of finite element method and applications to structures, thermal, 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 flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; pre-processing and post-processing techniques; term projects with computers. Letter grading. Mr. Chen, Mr. Klug (F,Sp)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion; two hours; outside study, six hours. Requisites: courses 101, 102, 107. Fundamental theory and individual component analysis of free, forced, and transient vibration of one or two degrees of freedom systems, including damping. Normal modes, coupling, and normal coordinates. Vibrational isolation devices, vibrations of continuous systems. Letter grading. Mr. Bendiksen (F)

171A. Introduction to Feedback and Control Systems: Dynamic Systems Control I. (4) Lecture, four hours; discussion; two hours; outside study, six hours. Enforced requisite: courses 107, 182A. Introduction to feedback principles, control systems design, and system stability. Modeling of physical systems in engineering and other fields; transform methods; controller design using Nyquist, Bode, and root locus methods; compensation; computer-aided analysis and design. Letter grading. Mr. M’Closkey (FWSp)


172. Control System Design Laboratory. (4) Lecture, four hours; laboratory; two hours; outside study, six hours. Enforced requisite: course 171A. Introduction to loop shaping controller design with application to laboratory electromechanical systems. Power spectral 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. Practical exercises are supported by weekly hands-on laboratory work. Letter grading. Mr. M’Closkey (Not offered 2014-15)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture, four hours; discussion; two hours; outside study, six hours. Requisite: Mathematics 33A. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault tree analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading. Mr. Bendiksen (W)

C175A. Probability and Stochastic Processes in Dynamic Systems. (4) Lecture, four hours; discussion; outside study, eight hours. Requisite: courses 107, 182A. Probability spaces, random variables, stochastic processes and sequences, expectation, conditional probability, characteristic functions, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C271A. Letter grading. Mr. Sprey (F)

CM180. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM150 and Electrical Engineering CM150L.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining and microelectromechanical systems (MEMS) laboratory. Design of MEMS and how these methods can be used to produce variety of MEMS, including microstructures, microcrosors, and microactuators. Students design microfabrication processes capable of achieving desired MEMS device. Concurrently scheduled with course CM280A. Letter grading. Mr. Chiu (F)

CM180L. Introduction to Micromachining and Microelectromechanical Systems (MEMS) Laboratory. (2) (Same as Bioengineering CM150L and Electrical Engineering CM150L.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20L, Physics 1A, 1B, 1C, 4AL, 4BL. Hands-on introduction to micromachining and micro electromechanical systems (MEMS) laboratory. Methods of micromachining and how these methods can be used to produce variety of MEMS, including microstructures, microcrosors, and microactuators. Students go through process of fabricating MEMS device. Concurrently scheduled with course CM280L. Letter grading. Mr. Chiu (F)

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 integrals, singularities, residues, Cauchy integrals; Laplace transform: properties, convolution, inversion; Fourier transform: properties, convolution, FTT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. Ghoniem (Not offered 2014-15)


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 arising in engineering. Separation of variables, eigenvalue problems, Sturm-Liouville theory, Development and use of special functions. Representation by means of orthonormal functions; Galerkin method. Use of series functions and transform methods. Letter grading. Mr. Eldredge, Mr. J. Kim (W)

182C. Numerical Methods for Engineering Applications. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses M20 (or Civil Engineering M20 or Computer Science 31), 94. Fundamentals in parametric curve and surface modeling, parametric spaces, blending functions, conics, splines and Bezier curve, coordinate transformations, algebraic and geometric form of surfaces, analytical properties of curve and surface, hands-on experience with CAD/CAM systems design and implementation. Letter grading. Mr. C-J. Kim (FWSp)

185. Introduction to Radio Frequency Identification and Its Application in Manufacturing and Supply Chain. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M20 or Civil Engineering M20 or Computer Science 31. Manufacturing today requires automated processes and identification of products, shipping of such products, and eventually use, maintenance, and recycling of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and assemblies of products allow them to be tracked as they move and transform through manufacturing supply chain. RFID tags have memory and small CPU that allows information about product status to be written, stored, and transmitted wirelessly. Tag data can then be forwarded by reader to enterprise 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 2014-15)


C187L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) 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 C287L. Letter grading. Mr. Y. Chen (FSp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) Lecture, four to two hours; outside study, four to eight hours. Special topics in mechanical and aerospace engineering for undergraduate students taught on experimental or temporary basis, such as taught by resident
and visiting faculty members. May be repeated once for credit with topic or instructor change. P/NP or letter grading. (W)

194. Research Group Seminars: Mechanical and Aerospace Engineering, (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research groups. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit. P/NP or letter grading.

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

**Graduate Courses**

231A. Convective Heat Transfer Theory. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 150A. Thermodynamic properties of materials and radiative energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading.

Ms. Lavine (W)

231B. Radiation Heat Transfer. (4) Lecture, four hours; outside study, eight hours. Requisites: course 105D. Radiative properties of materials and radiative energy transfer. Emphasis on fundamental concepts, including energy levels and electromagnetic waves as well as analytical methods for calculating radiative properties and radiation in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading.

Mr. Pilon (Sp)


Ms. Lavine (F)

231G. Microscopic Energy Transport. (4) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electrons, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering, 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)


Mr. Pilon (Sp)

235A. Nuclear Reactor Theory. (4) Lecture, four hours; outside study, eight hours. Requisite: course 182A. Underlying physics and mathematics of nuclear reactor fission core design. Diffusion theory, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transmutation. Letter grading.

Mr. Abdou

237. Design and Analysis of Smart Grids. (4) Lecture, four hours; outside study, eight hours. Demand response; transactive/price-based load control; home-area network, smart energy profile; advanced metering infrastructure; renewable energy integration; energy system component efficiency and integration; microgrids; grid stability; energy storage and electric vehicles-simulation; monitoring; distribution and transmission grids; consumer-centric technologies; wireless connectivity; control; wireless, wired, and powerline communications for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational awareness; phasor measurements; analytical methods and tools for monitoring and control. Concurrently scheduled with course C137. Letter grading.

Mr. Abdou


Mr. Abdou

237D. Fusion Engineering and Design. (4) Lecture, four hours; outside study, eight hours. Fusion reactions such as nuclear fusion and inertial confinement fusion. Plasma requirements for controlled fusion. Plasma-surface interactions. Fusion reactor concepts and technological components. Analysis and design of high heat flux components, energy conversion and tritium breeding components, radiation shielding, magnets, and heating. Letter grading.

Mr. Abdou

239B. Seminar: Current Topics in Transport Phenomena. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measurement techniques. May be repeated for credit. S/U grading.

Mr. Abdou

239F. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measurement techniques. May be repeated for credit with topic change. S/U grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.

239H. Special Topics in Fusion Physics, Engineering, and Technology. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced treatment of subjects selected from research areas in fusion science and engineering, such as instabilities in burning plasmas, alternate fusion confinement concepts, inertial confinement fusion, advanced concepts, and hybrid systems, and fusion reactor safety. May be repeated for credit with topic change. S/U grading.

CM240. Introduction to Biomechanics. (4) (Same as Bioengineering CM240.) Lecture, four hours; discussion, two to four hours; outside study, six hours. Enforced requisites: courses 101, 102, and 156A or 166A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics of and kinematics of fluid mechanics applications. 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 fluid mechanics at graduate level, with emphasis on incompressible flows. Lagrangian and Eulerian equations, constitutive relations, exact solutions on the Navier/Stokes equations, vorticity dynamics, decomposition of flow fields, potential flow. Letter grading.

Mr. Abdou

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Fundamental principles of fluid dynamics applied to study of fluid resistance. States of fluid motion discussed in order of increasing Reynolds number; wakes, boundary layers, instability, transition, and turbulent shear flows. Letter grading.

Ms. Karagozian, Mr. J. Kim (Sp)

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 150A, 150B, 182C. Control required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.


Mr. Zhong (W)

250E. Spectral Methods in Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 182A, 182B, 182C, 250A, 250B. Introduction to basic concepts and techniques of various spectral methods applied to solving partial differential equations. Particular emphasis on techniques of solving unsteady three-dimensional Navier/Stokes equations. Topics include spectral representation of functions, discrete Fourier transform, etc. Letter grading.

Mr. Zhong (W)

250F. Hypersonic and High-Temperature Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250C. Molecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermodynamics for calculation gas properties, equilibrium flows of real gases, vibrational and chemical rate processes, nonequilibrium real gases, and computational fluid dynamics methods for nonequilibrium hypersonic flows. Letter grading.

Mr. Zhong (W)

C250G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 250C. Molecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical thermodynamics for calculation gas properties, equilibrium flows of real gases, vibrational and chemical rate processes, nonequilibrium real gases, and computational fluid dynamics methods for nonequilibrium hypersonic flows. Letter grading.

Mr. Zhong (W)

250M. Introduction to Microfluids/Nanofluids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Introduction to fundamentals of microfluidics and nanofluidics. Characterization and testing of nanofluidic devices; fluid mechanics at micro/Nanoscale. Characterization of nanofluids; effects of microfluids and nanofluids; pulsatile fluid flow in circulatory system; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial diseases. Concurrently scheduled with course C150G. Letter grading.

Mr. Eldredge (Sp)

250N. Introduction to Microfluidics/Nanofluids. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Introduction to fundamentals of microfluidics and nanofluidics. Characterization and testing of nanofluidic devices; fluid mechanics at micro/Nanoscale. Characterization of nanofluids; effects of microfluids and nanofluids; pulsatile fluid flow in circulatory system; rheology of blood; transport in microcirculation; role of fluid dynamics in arterial diseases. Concurrently scheduled with course C150G. Letter grading.

Mr. Karagozian

C250R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 103A, 105A. Fundamentals of rocket engine design, aircraft engine cycle analysis and component performance, component matching, advanced flight dynamics topics. Concurrently scheduled with course C150P. Letter grading.

Mr. Karagozian

Ms. Karaman, Mr. Witz (Sp)

25A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Mechanisms by which laminar flows can become unstable and lead to the turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; boundary layer instability. Nonlinear aspects: sufficient criteria for stability, subcritical instabilities, supersonic states, transition to turbulence. Letter grading.

Mr. Zhong


Mr. J. Kim


Ms. Karaman

25D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: molecular collisions, distribution functions and averaging, semiequilibrium and ab initio potential surfaces, trajectory calculations, statistical reaction rate theories. Practical examples of large-scale chain mechanisms from combustion chemistry of several elements, etc. Letter grading.

Mr. Witz


Mr. Witz


Mr. Zhong

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Concepts of stability; state-space interpretation; stability determination by simulation, linearization, and Lyapunov direct method; the Hamiltonian as a Lyapunov function; nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and nonlinear resonances; Application to mechanical systems. Letter grading.

Mr. Clancy

256A. Linear Elasticity. (4) (Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Linear elastic solids: stress-strain; infinitesimal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plate elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Green’s functions; boundary integral equation method. Letter grading.

Mr. Mal (F)

M256B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics of deformation, material and spatial coordinate systems, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws; Cauchy and Piola stresses, Cauchy equations of motion, energy stored, hyperelasticity equations; weak relations, elasticity, hyperelasticity, thermoelasticity, linearization of field equations; solution of selected problems. Letter grading.

Mr. Dong, Mr. Mal (W)


Mr. Gupta

256F. Analytical Fracture Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Review of modern fracture mechanics, elementary stress analyses; analytical and numerical methods, factor of safety, stress intensity factors; engineering applications in stiffened structures, pressure vessels, plates, and shells. Letter grading.

Mr. Gupta

M257A. Elastodynamics. (4) (Same as Earth, Planetary, and Space Sciences M257A.) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves in unbounded isotropic, anisotropic, and dissipative solids. Half-space problems. Guided waves in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading.

Mr. Mal

258A. Nanomechanics and Micromechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Analytical and computational modeling methods to describe mechanics of materials at scales ranging from atomistic through microstructure or transitional and up to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics, discrete element modeling, cellular automata) and their applications at nanoscale. Developments and applications of dislocation dynamics and statistical mechanics methods in areas of nanostructure and microstructure self-assembly, self-organization, plastic deformation, material instabilities, and failure phenomena. Presentation of technical applications of these emerging modeling techniques to surfaces and interfaces, grain boundaries, dislocations and defects, surface growth, quantum dots, nanotubes, nanostructures, thin films (e.g., optical thermal barrier coatings and ultrastrong 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 research problems leading to term paper or oral presentation (possible help from guest lecturers). Letter grading.

Mr. Kavehpour

259B Seminar: Advanced Topics in Solid Mechanics. (4) Seminar; four hours; outside study, eight hours. Advanced study in various fields of solid mechanics on topics which may vary from term to term. Topics include dynamics, elasticity, plasticity, and stability of solids. Letter grading.

Mr. Mal

260. Current Topics in Mechanical Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, and student presentations and projects in current topics in mechanical engineering. May be repeated for credit. S/U grading.


Mr. Klug (F)


Mr. Klug (W)


Mr. Carman

263A. Analytical Foundations of Motion Controllers. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: courses 163A, 254A. Theory of motion control for modern computer-controlled machines; multitask computer-controlled machines; machine kinematics and dynamics; multiaxis motion coordination; coordinated motion with desired speed and acceleration; jerk analysis; motion command generation; theory and design of controller interpolators; motion trajectory design and analysis; geometry-speed-sampling time relationships. Letter grading.

Mr. Ghoniem

263B. Spacecraft Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Recommended: course 255B. Modeling, dynamics, and control of space vehicles and real-spacecraft dynamics; spinup through resonance, spinning rocket dynamics; environmental torques in space, modeling and model reduction of flexible systems. Letter grading.

Mr. Witz


Mr. Ghoniem (F)

263D. Advanced Robotics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 263C. Foundation: courses 155, 171A, 263C. Motion planning and control of articulated dynamic systems: nonlinear joint control, experiments in joint control and multi-axis control; simulation, motion planning, trajectory planning, motion optimization, dynamic performance and manipulator design, kinematic redundancies, motion planning of manipulators in space, obstacle avoidance. Letter grading.

Mr. Ghoniem


Mr. Bendiksen (F)
269B. Advanced Dynamics of Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 269A. Introduction to dynamics of several-body, non-linear systems with emphasis on the response of structures to dynamic loadings. Stresses and deflections in structures. Structural damping and self-induced vibrations. Letter grading. Mr. Bendiksen

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course 269A. Presentation of field of aeroelasticity from a systems analysis viewpoint applicable to flight structures, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Flow induced instabilities and response of structural gradients. Letter grading. Mr. Bendiksen (F)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engineering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course 171A or Electrical Engineering 141. State-space description of linear time-invariant (LTI) and time-variant (TV) 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 for single-input, single-output systems, and observers; separation principle. Connections with transfer function techniques. Letter grading. Mr. M'Closkey (F)

270B. Linear Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, infinite-time and finite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stabilizability, observability, and detectability solutions. Letter grading. Mr. Gibson (W)

M270C. Optimal Control. (4) (Same as Chemical Engineering M280C and Electrical Engineering M240C.) Lecture, four hours; outside study, eight hours. Requisite: course 270B. Applications of variational methods, Pontryagin maximum principle, Hamiltonian systems and optimal control, conditional extremum problems. Focus on Riccati equations, Gauss/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C175A. Letter grading. Mr. Speyer (F)

271A. Probability and Stochastic Processes in Dynamic Systems. (4) (Formerly numbered 271A.) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 171, 182A. Probability spaces, random variables, stochastic sequences and processes, conditional expectation, conditional probability. Gaussian/Markov processes, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C175A. Letter grading. Mr. Speyer (F)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course C271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Speyer (W)

271C. Stochastic Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271B. Stochastic dynamic programming, certainty equivalent (pie) feedback law, information statistics; linear-quadratic-Gaussian problem, linear-exponential-Gaussian problem. Relationship between stochastic control and robust control. Letter grading. Mr. Speyer (F)

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications. Topics selected from process control, differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer

M272A. Nonlinear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical Engineering M242A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Chemical Engineering M280A or Electrical Engineering M240A. State-space modeling and simulations of time-variant and time-variant nonlinear dynamic systems with emphasis on stability. Lyapunov theory (including converse theorems), invariance, center manifold theorems, absolute stability and small-gain theorem. Letter grading.

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level analysis and design of multi-variable control systems. Multivariable loop-shaping, performance requirements, model uncertainty representations, and robustness covered in detail from frequency domain perspective. Structured singular value and its application to controller synthesis. Letter grading. Mr. M'Closkey (Sp)

275A. System Identification. (4) Lecture, four hours; outside study, eight hours. Methods for identification of dynamic systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include linear, time-invariant, time-varying, and nonlinear models. Discussion of applications in mechanical and aerospace engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading. Mr. Gibson (Sp)


modes, fiber coupling, types of fiber: single and multimode. Concurrently scheduled with course 156E. Letter grading. 

Mr. Chiu

M287. Nanoscience and Technology. (4) (Same as Electrical Engineering M257.) Lecture, four hours; outside study, eight hours. Enforced requisite: course CM298A. Introduction to fundamentals of nanoscience and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication; nanolithography; nanomaterials, nanoelectronics, and nanobiotechnology. Introduction to new knowledge and techniques in nanoareas to understand scientific principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading. 

Mr. Y. Chen (W)

C287L. Nanoscale Fabrication, Characterization, and Biodetection Laboratory. (4) Lecture, two hours; laboratory, three hours; outside study, seven hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biodetection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) nanofabrication, nanocharacterization (AFM, 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 (F,Sp)

288. Laser Microfabrication. (4) Lecture, four hours; outside study, eight hours. Requisites: Materials Science 104, Physics 17. Science and engineering of laser microscopic fabrication of advanced materials, including semiconductors, metals, and insulators. Topics include fundamentals in laser interactions with advanced materials, transport issues (thermo, mass, chemical, carrier, etc.) in laser microfabrication, state-of-art optics and instrumentation for laser microfabrication, applications such as rapid prototyping, surface modifications (physical/chemical), micromachines for three-dimensional MEMS (microelectromechanical systems) and data storage, up-to-date research activities. Student term projects. Letter grading.

294. Computational Geometry for Design and Manufacturing. (4) Lecture, four hours; outside study, eight hours. Requisite: 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, computing methods for surface design and manufacture, and current research topics in computational geometry for CAD/CAM systems. Letter grading. 

Mr. Ghoniem

295B. Internet-Based Collaborative Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 94, 184. Exploration of advanced to-culture of the art concepts in Internet-based collaborative design, including software environments to connect designers over internet, networked virtual media graphics environments such as high-end virtual reality systems, mid-range graphics, and low-end mobile device-based systems, and multifunctional design collaboration and software tools to support it. Letter grading. 

Mr. Gadh

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 system function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. 

Mr. Gadh


Mr. Ghoniem (F)


Mr. Ghoniem

297A. Material Processing in Manufacturing. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 183. Thermodynamics, principles of material processing: phase equilibria and transitions, transport mechanisms of heat and mass, nucleation and growth of microstructure. Applications in casting/solidification, welding, consolidation, chemical vapor deposition, infiltration, composites. Letter grading. 

Mr. Ghoniem


Mr. Lavine

C298. 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. 

W

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

375. Teaching Apprentice Practicum. (1 to 4) Seminar, to be arranged. Preparation: apprentice personnel employment as 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. 

Ms. Lavine (F,W,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.

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.
Master of Science in Engineering Online Program

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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 24.

The following introductory information is based on the 2014-15 edition of Program Requirements for UCLA Graduate Degrees. Complete annual editions of Program Requirements are available at http://grad.ucla.edu/gasas/library/pgmrqintro.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 background 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.

Electrical Engineering
Kung Yao, Ph.D. (Electrical Engineering), Director; yao@ee.ucla.edu

The electrical engineering program covers a broad spectrum of specializations in 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.

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@seas.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, microelectronics 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.

Materials Science
Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Director; jyang@seas.ucla.edu

Materials engineering is concerned with the design, fabrication, and testing of engineering materials that must simultaneously fulfill dimensional properties, quality control, and economic requirements. Several manufacturing steps may be involved: (1) primary fabrication, such as solidification or vapor deposition of homogeneous or composite materials, (2) secondary fabrication, including shaping and microstructural control by operations such as mechanical working, machining, sintering, joining, and heat treatment, and (3) testing, which measures the degree of reliability of a processed part, destructively or nondestructively.

Mechanical Engineering
Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Director; ajit@seas.ucla.edu

The mechanical engineering program offers students advanced study in a number of areas, including mechanical behavior of materials, structures, fluids, controls, and manufacturing.

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/programs/system-engineering for further information.

Schoolwide Programs, Courses, and Faculty

UCLA
6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601

(310) 825-0580
http://engineer.ucla.edu

Professors Emeriti
Allen B. Rosenstien, Ph.D.
Bonham Spence-Campbell, E.E.

Graduate Study
For information on graduate admission to the schoolwide engineering programs and requirements for the Engineer degree and certificate of specialization, see Graduate Programs, page 24.

Faculty Areas of Thesis Guidance

Professors Emeriti
Allen B. Rosenstien, Ph.D. (UCLA, 1958)

Educational delivery systems, computer-aided design, design, automatic controls, magnetic controls, nonlinear electronics

Bonham Spence-Campbell, E.E. (Cornell, 1939)

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

Lower Division Courses

10A. Introduction to Complex Systems Science. (4) 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 multiagent computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

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

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 the difference between engineering disciplines.
and functions engineers perform. Development of skills and knowledge through academic coursework and by working in engineering team projects. Preparation for professional practice. Option for students interested in academic careers only. Mr. Wesel (F)

95. Internship Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to freshmen/sophomores. Internship studies course supervised by associate dean or designated faculty members. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be applied toward any academic requirements. Placement fee required. Individual contract with associate dean required. P/NP grading. Mr. Wesel (F, W, Sp)

98. What Students Need to Know about Careers in Engineering. (2) Seminar, four hours. Introduction to skills and aptitudes that most engineers require in their careers and description of big picture of engineering careers. Integrating framework provided to relate specifics of engineering courses to real world of engineering practice. Mr. Silverstein (F)

99. Student Research Program. (1 to 2) Tutorial (supervised research). Requires major scholarship. 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 a minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper Division Courses

M101. Principles of Nanoscience and Nanotechnology. (4) (Same as Materials Science M105.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemistry 20A, 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 nanometers) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron 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. Kolins (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 desired functions in engineering systems, where mechanical, material, and electronic components are designed to perform desirable functions in engineering systems, and chemical, optical, and electronic properties, including transport of materials and energy, are manipulated to perform desired functions. Letter grading. Mr. Hoek (Sp)

110. Introduction to Technology Management and Entrepreneurship. (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, economic, political, and social) environment and management. How individuals, firms, and governments impact successful commercialization of high technology products and services. Letter grading.

111. Introduction to Finance and Marketing for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of finance and marketing research and practice as they relate to commercialization. Internal (within firm) and external (in marketplace) marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, internal rate of return, return on assets, return on equity, return on investment, interest rates, cost of capital, and product, price, positioning, and promotion. Use of market research, segmentation, and forecasting in management of technologically innovative products and ventures._mr. Monbouquette (FW)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical components of entrepreneurship, finance, marketing, human resources, and accounting disciplines as they impact management of technology commercialization. Topics include intellectual property management, team building, market forecasting, and entrepreneurship. 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)

113. Product Strategy. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for juniors/seniors. Introduction to current management concept of product development. Topics include product strategy, product platform, and product lines; 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 by speakers from industry. Letter grading. Mr. Pao (W)

120. Entrepreneurship for Scientists and Engineers. (2) Seminar, two hours; outside study, four hours. Designed for graduate students. Identification of business opportunities and outline of basic requisites for viable business plans, followed by specific topics related to securing basic assets and services needed to execute these plans. P/NP grading. Mr. Wesel (Sp)

180. Engineering of Complex Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for junior/senior engineering majors. 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 understanding and being able to form strategies for solving complex problems. Letter grading. Mr. Wesel (Sp)

183EW. Engineering and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or IDS 30. Prerequisites: course M103. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems, where biological components are reengineered and rewired to perform desired functions in engineering systems, where mechanical, material, and software components are designed to perform desired functions in engineering systems, and chemical, optical, and electronic properties, including transport of materials and energy, are manipulated to perform desired functions. Letter grading. Mr. Wesel (Sp)

183EW. Art of Engineering Endeavors. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or IDS 30. Prerequisites: course M103. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems, where biological components are reengineered and rewired to perform desired functions in engineering systems, where mechanical, material, and software components are designed to perform desired functions in engineering systems, and chemical, optical, and electronic properties, including transport of materials and energy, are manipulated to perform desired functions. Letter grading. Mr. Wesel (Sp, W, Sp)

185EW. Special Courses in Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading.

195. Internship Studies in Engineering. (2 to 4) Tutorial, two to four hours. Limited to juniors/seniors. Internship studies course supervised by associate dean or designated faculty members. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be applied toward any academic requirements. May be repeated for credit. Individual contract with associate dean required. P/NP grading. Mr. Wesel (F, W, Sp)

199. Directed Research in Engineering. (2 to 4) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F, W, Sp)

Graduate Courses

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program managers with tools to support decision making. Focus on 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. (W)
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 work experience. Integrated logistic support (ILS) is major driver of system life-cycle cost and one key element of system engineering activities. Overview of engineering disciplines critical to this function—reliability, maintainability, and supportability—and their 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. Mr. Lynch, Mr. Wesel


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 composing systems from network security, computer security, data security, 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 operated for specific levels of trust. Aspects include assessing vulnerability and risk for systems, establishing protection principles, and using them as guide to formulate system architectures; translating architecture into system design and verifying correctness of design; and constructing and following 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 enterprises and intended for students who wish to complement their technical education with introduction to entrepreneurship. Letter grading. Mr. Abe, Mr. Cong, Mr. Wesel (W)

299. Capstone Project. (Activity, 10 hours. Preparation: completion of minimum of four 200-level courses in online M.S. program. Project course that satisfies UCLA final comprehensive examination requirement of M.S. online degree in Engineering. Project is completed under individual guidance from UCLA Engineering faculty member and incorporates advanced knowledge learned in M.S. program of study. Letter grading. Mr. Lynch (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)


471A-471B-471C. Engineer in General Environment. (3-3-1.5) Lecture, three hours (courses 471A, 471B) and 90 minutes (course 471C). Limited to Engineering Executive Program students. Influences of human relations, laws, social sciences, humanities, and fine arts on development and utilization of natural and human resources. Interaction of technology and society past, present, and future. Change agents and resistance to change. S/U or letter (471A) grading; In Progress (471B) and S/U or letter (471C) grading.

472A-472D. Engineer in Business Environment. (3-3-1.5) Lecture, three hours (courses 472A, 472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Language of business for engineering executive. Accounting, finance, business economics, business law, and marketing. Laboratory in organization and management problem solving. Analysis of actual business problems of firm, community, and nation, provided through cooperation and participation with California business corporations and government agencies. In Progress (472A, 472C) and S/U or letter grading (credit to be given on completion of courses 472B and 472D).

473A-473B. Analysis and Synthesis of Large-Scale Systems. (3-3) Lecture, two and one-half hours. Limited to Engineering Executive Program students. Problem area of modern industry or government is selected as class project, and its solution is synthesized using quantitative tools and methods. Project also serves as laboratory in organization for goal-oriented technical group. In Progress (473A) and S/U (473B) grading.

495A. Teaching Assistant Training Seminar. (4) Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Limited to graduate engineering students. Seminar on communication of engineering principles, concepts, and methods, preparation, organization of material, presentation, use of visual aids, grading, advising, and rapport with students. S/U grading.

M495B. Supervised Teaching Preparation. (2) (Same as English Composition M495E) Seminar, two hours. Required of all teaching assistants for Engineering writing courses not exempt by appropriate departmental or program training. Training and mentoring, with focus on composition pedagogy, assessment 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, and conducting peer reviews and conferences. S/U grading. (F)

M495C. Supervised Teaching Preparation. (2) (Same as English Composition M495E) Seminar, one hour. Requisite: course M495B. Required of all teaching assistants in their initial term of teaching Engineering writing courses. Mentoring in group and individual 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. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F,W,Sp)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of UCLA graduate advisor 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 Expeditions in Computing Program and cTrans Award

Jason Cong, Ph.D. (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 computing platforms and the associated compilation tools and runtime management environment to support domain-specific computing. The recent focus is on design and implementation of accelerator-rich architectures, from single chips to data centers. It also includes highly automated compilation tools and runtime management software systems for customizable heterogeneous platforms, including multi-core CPUs, many-core GPUs, and FPGAs, as well as 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 or supercomputer-in-a-cluster that can be customized to an application domain to enable disruptive innovations in that domain. This approach has been successfully demonstrated in the domain of medical image processing.

CDSC 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. Core funding for CDSC is provided by the National Science Foundation with a $10 million award from the 2009 Expeditions in Computing Program, which is the largest single investment made by the NSF Directorate for Computer and Information Science and Engineering (CISE). In July 2014, CDSC was awarded an additional $3 million by the Intel Corporation with matching support from NSF under its Innovation Transition (cTrans) program. This award supports CDSC’s follow-on research on accelerator-rich architectures with applications to health care, in which personalized cancer treatment is added as an application domain in addition to medical imaging. Oregon Health and Science University also joins as a research partner under the cTrans program.

Center for Encrypted Functionalities

National Science Foundation Secure and Trustworthy Cyberspace FRONTIER Award

Amit Sahai, Ph.D. (Computer Science), Director; http://cs.ucla.edu/cef/

The Center for Encrypted Functionalities tackles the deep and far-reaching problem of general-purpose program obfuscation, which aims to make an arbitrary computer program unintelligible while preserving its functionality. Viewed in a different way, the goal of obfuscation is to enable software that can keep secrets: it makes use of secrets, but such that these secrets remain hidden even if an adversary can examine the software code in its entirety and analyze its behavior as it runs. Secure obfuscation could enable a host of applications, from hiding the existence of many vulnerabilities introduced by human error to hiding cryptographic keys within software.

The center's primary mission is to transform program obfuscation from an art to a rigorous mathematical discipline. In addition to its direct research program, the center organizes retreats and workshops to bring together researchers to carry out its mission. The center also engages in high-impact outreach efforts, such as the development of free massive open online courses (MOOCs).

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

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 beyond-Boolean computation. Its main focus is nonconventional material solutions ranging from semiconductors and dielectrics to metallic materials as well as their correlated quantum properties. FAME creates and investigates new, nonconventional, atomic-scale engineered materials and structures of multifunction oxides, metals, and semiconductors to accelerate innovations in analog, logic, and memory devices for revolutionary impact on the semiconductor and defense industries.

FAME is one of six university-based research centers established by SRC through its Semiconductor Technology Advanced Research network (STARnet). Funded by DARPA and the U.S. semiconductor and supplier industries as a public-private partnership, STARnet projects help maintain U.S. leadership in semiconductor technology vital to U.S. prosperity, security, and intelligence. FAME expects to receive a total of $35 million in funding through 2018.

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

The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) is a 10-year program focused on miniaturizing electromagnetic devices and built around a three-pillar strategy involving research, translation, and education. The research strategy engages the best researchers from the four TANMS campuses (UCLA, UC Berkeley, Cornell University, and California State University, Northridge) to understand and develop new nanoscale multiferroic concepts. The fundamental research activities work synergistically with the center’s industrial partners to translate the concepts into applications such as memory, antennas, and motors. These research and translational efforts rely on a workforce of postgraduate,
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 easily 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.

**Center of Excellence for Green Nanotechnologies**

Kang L. Wang, Ph.D. (Electrical Engineering), Director; http://www.cegn-kacst-ucla.org

The Center of Excellence for Green Nanotechnologies (CEGN) undertakes frontier research and development in the areas of nanotechnology in energy and nanoelectronics. It tackles major issues of scaling, energy efficiency, energy generation, and energy storage faced by the electronics industry. CEGN researchers are innovating novel solutions through a number of complementary efforts that minimize power usage and cost without compromising electronic device performance. The approach is based on the integration of magnetic, carbon-based, organic, and optoelectronic materials and devices.

King Abdullah City for Science and Technology (KACST) in Saudi Arabia and the Henry Samueli School of Engineering and Applied Science collaborate in CEGN under KACST’s established Joint Center of Excellence Program (JCEP) to promote educational technology transfer and research exchanges. KACST has an agreement with UCLA for research in nanoelectronics and clean energy for the next 10 years. KACST is both Saudi Arabia’s national science agency and its premier national laboratory. CEGN expects to receive an additional $11 million over the next six years in addition to the $3.7 million it has already received.

**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.

**Named Data Networking Project**

National Science Foundation Future Internet Architecture (FIA) Program

Lixia Zhang, Ph.D. (Computer Science), Principal Investigator; http://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. The TCP/IP architecture was designed to create a communication network where packets named only communication endpoints. Sustained growth in e-commerce, digital media, social networking, and smartphone applications has led to dominant use of the Internet as a distribution network. Solving distribution problems through a point-to-point communication protocol is complex and error-prone. This project investigates a new Internet architecture called Named Data Networking (NDN). NDN changes the host-centric TCP/IP architecture to a data-centric architecture. This conceptually simple shift has far-reaching implications for how we design, develop, deploy, and use networks and applications. Today’s TCP/IP architecture uses addresses to communicate; NDN directly uses application data names to fetch data. TCP/IP secures the data container and communication channels; NDN directly secures the data, decoupling trust in data from trust in hosts. The project takes an application-driven, experimental approach to design and build a variety of applications on NDN to drive the development and deployment of the architecture and its supporting modules, test prototype implementations, and encourage community use, experimentation, and feedback into the design. The new Future Internet Architectures—Next Phase (FIA-NP) program began in May 2014. The Named Data Networking Project is now under FIA-NP funding.

**Smart Grid Energy Research Center**

Rajit Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director; http://smartgrid.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 partnerships 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.

**WIN Institute of Neurotronics**

NanoElectronics Research Initiative National Institute of Excellence

Kang L. Wang, Ph.D. (Electrical Engineering), Director; http://win-nano.org

Successor to the Western Institute of Nanoelectronics (WIN), the WIN Institute of Neurotronics (WINs) focuses on cutting-edge research including nanostructures for high-efficiency solar cells, patterned nanostructures for integrated active optoelectronics on silicon, and carbon nanotube circuits. Through the multidisciplinary research efforts of WINs, the National Institute of Standards and Technology (NIST) awarded UCLA $6 million to build the Western Institute of Nanotechnology on Green Engineering and Metrology (WIN-GEM) building as part of the Engineering Building I replacement, which broke ground in 2013.
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.wirelesshealth.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 accumulative impairments associated with aging. These home-health and mobile-health technologies can serve as monitoring devices 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 Wi-Fi transmission using telephones and other convenient devices. To pursue these applications, WHI collaborators include 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. WHI education programs span high school, undergraduate, and graduate students, and provide training in end-to-end product development and delivery for WHI program managers.

WHI products appear in diverse areas including motion sensing, wound care, orthopaedics, digestive health and process monitoring, advancing athletic performance, and many others. Clinical trials validating WHI technology are underway at 10 institutions. WHI products developed by the UCLA team are now in the marketplace in the U.S. and Europe. Physicians, nurses, therapists, other providers, and families can apply these technologies in hospital and community practices. Academic and industry groups can leverage the organization of WHI to rapidly develop products in complete-care programs and validate in trials. WHI welcomes new team members and continuously forms new collaborations with colleagues and organizations in medical science and health care delivery.
# B.S. in Aerospace Engineering Curriculum

## Freshman Year

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<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
<td>4</td>
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<tr>
<td></td>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
<td>5</td>
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<tr>
<td></td>
<td>Mathematics 31A — Differential and Integral Calculus</td>
<td>4</td>
</tr>
<tr>
<td>2nd</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td></td>
<td>Mathematics 31B — Integration and Infinite Series</td>
<td>4</td>
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<td></td>
<td>Physics 1A — Mechanics</td>
<td>5</td>
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<tr>
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## Sophomore Year

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## Senior Year

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<td>Mechanical and Aerospace Engineering 166A — Analysis of Flight Structures</td>
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<td>Mechanical and Aerospace Engineering 157A — Fluid Mechanics and Aerodynamics Laboratory</td>
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**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 21 for details).

** See page 100 for a list of electives.
# B.S. in Bioengineering Curriculum

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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Bioengineering 100 — Bioengineering Fundamentals</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Bioengineering 167L — Bioengineering Laboratory</td>
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<td>Life Sciences 3 — Introduction to Molecular Biology</td>
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<td>Life Sciences 23L — Introduction to Laboratory and Scientific Methodology</td>
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<td>Bioengineering 120 — Biomedical Transducers</td>
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<td>Bioengineering 110 — Biotransport and Bioreaction Processes</td>
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<td>Bioengineering 176 — Principles of Biocompatibility</td>
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<td>Bioengineering 177A — Bioengineering Capstone Design I</td>
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<td>Bioengineering 177B — Bioengineering Capstone Design II</td>
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**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 21 for details).
** Bioengineering electives include courses C101, C102, CM103, C104, C105, C106, C131, CM140, CM145, C147, CM150, C155, C170, C171, CM178, C179, 180L, C183, C185, CM186, CM187. 199 (8 units maximum).
† Restricted electives include Bioengineering C101, C106, C131, C155, M260 (a petition is required for M260).
### Freshman Year

**1st Quarter**
- Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering .................................................. 1
- Chemistry and Biochemistry 20A — Chemical Structure ......................................................................................... 4
- English Composition 3 — English Composition, Rhetoric, and Language ................................................................. 5
- Mathematics 31A — Differential and Integral Calculus .............................................................................................. 5

**2nd Quarter**
- Chemistry and Biochemistry 20B — Chemical Energetics and Change ................................................................. 4
- Mathematics 31B — Integration and Infinite Series .................................................................................................. 5
- Physics 1A — Mechanics ........................................................................................................................................ 5
- HSSEAS GE Elective* ........................................................................................................................................... 5

**3rd Quarter**
- Chemistry and Biochemistry 20L — General Chemistry Laboratory ................................................................. 3
- Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity .............................................. 4
- Mathematics 32A — Calculus of Several Variables ................................................................................................. 4
- Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory .......... 7

### Sophomore Year

**1st Quarter**
- Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering .................................. 4
- Chemistry and Biochemistry 30AL — General Chemistry Laboratory II ............................................................... 4
- Mathematics 32B — Calculus of Several Variables ................................................................................................. 4
- Physics 1C/4BL — Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory .......... 7

**2nd Quarter**
- Chemical Engineering 102A — Thermodynamics I ............................................................................................... 4
- Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy .............. 4
- Mathematics 33A — Linear Algebra and Applications ............................................................................................... 4
- HSSEAS GE Elective* ........................................................................................................................................... 5

**3rd Quarter**
- Chemical Engineering 102B — Thermodynamics II ......................................................................................... 4
- Civil and Environmental Engineering M20 — Introduction to Computer Programming with MATLAB .... 4
- Mathematics 33B — Differential Equations ........................................................................................................... 4
- HSSEAS Ethics Course ........................................................................................................................................ 4

### Junior Year

**1st Quarter**
- Chemical Engineering 101A — Transport Phenomena I ......................................................................................... 4
- Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering ........................................................................................................................................... 4
- Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics .................. 4

**2nd Quarter**
- Chemical Engineering 101B — Transport Phenomena II: Heat Transfer .......................................................... 4
- Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I .................................... 4
- HSSEAS GE Elective* ........................................................................................................................................... 5

**3rd Quarter**
- Chemical Engineering 101C — Mass Transfer ....................................................................................................... 4
- Chemical Engineering 103 — Separation Processes ................................................................................................. 4
- Chemistry and Biochemistry 153A — Biochemistry: Introduction to Structure, Enzymes, and Metabolism ... 4

### Senior Year

**1st Quarter**
- Chemical Engineering 104B — Chemical and Biomolecular Engineering Laboratory II ..................................... 6
- Chemical Engineering 106 — Chemical Reaction Engineering ............................................................................. 4
- Chemical Engineering Elective ................................................................................................................................. 4
- Technical Breadth Course* ........................................................................................................................................ 4

**2nd Quarter**
- Chemical Engineering 107 — Process Dynamics and Control ............................................................................. 4
- Chemical Engineering 108A — Process Economics and Analysis ........................................................................... 4
- HSSEAS GE Elective* ........................................................................................................................................... 5
- Technical Breadth Course* ........................................................................................................................................ 4

**3rd Quarter**
- Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis ............................. 4
- Chemical Engineering Elective ................................................................................................................................ 4
- Technical Breadth Course* ........................................................................................................................................ 4

### 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 21 for details).
## B.S. in Chemical Engineering

### Biomedical Engineering Option Curriculum

### Freshman Year

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### Sophomore Year

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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Chemistry and Biochemistry 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Life Sciences 3 — Introduction to Molecular Biology</td>
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### Senior Year

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### TOTAL | Units | 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 21 for details).
# B.S. in Chemical Engineering

## Biomolecular Engineering Option Curriculum

### FRESHMAN YEAR

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### SOPHOMORE YEAR

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### JUNIOR YEAR

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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 C115 — Biochemical Reaction Engineering</td>
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<td>Chemical Engineering 107 — Process Dynamics and Control</td>
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<td>Chemical Engineering 108A — Process Economics and Analysis</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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### TOTAL

190

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**B.S. in Chemical Engineering**

**Environmental Engineering Option Curriculum**

**FRESHMAN YEAR**

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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Chemical Engineering 101A — Transport Phenomena I.</td>
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<td>Chemical Engineering 101B — Transport Phenomena II.</td>
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<td>Chemistry and Biochemistry 20L — General Chemistry Laboratory</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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**SOPHOMORE YEAR**

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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mathematics 33B — Differential Equations</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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**JUNIOR YEAR**

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<td>Mathematics 113A — Physical Chemistry: Introduction to Quantum Mechanics</td>
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<td>Chemical Engineering 103B — 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 104A — Chemical and Biomolecular Engineering Laboratory I</td>
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<td>Chemical Engineering 108A — Process Economics 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 21 for details).
# B.S. in Chemical Engineering

## Semiconductor Manufacturing Engineering Option Curriculum

### FRESHMAN YEAR

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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Chemistry and Biochemistry 20B — Chemical Energetics and Change</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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### JUNIOR YEAR

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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 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</td>
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<tr>
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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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**TOTAL 190**

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## B.S. in Civil Engineering Curriculum

### Freshman Year

<table>
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<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids.</td>
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<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
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<td>Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)</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>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics.</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>Civil and Environmental Engineering 110 — Introduction to Probability and Statistics for Engineers</td>
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### Total

187 or 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 21 for details).
† Must include required courses for two of the major field areas listed on page 48.
# B.S. in Computer Science Curriculum

### FRESHMAN YEAR

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<td>Computer Science 33 — Introduction to Computer Organization</td>
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### SOPHOMORE YEAR

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<td>Mathematics 61 — Introduction to Discrete Structures</td>
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<td>Computer Science 111 — Operating Systems Principles</td>
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<td>Computer Science M152A or Electrical Engineering M116L — Introductory Digital Design Laboratory</td>
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<td>Computer Science 131 — Programming Languages</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory</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 21 for details).
* See page 60 for list of electives.
B.S. in Computer Science and Engineering Curriculum

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* Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and HSSEAS GE (see page 21 for details).
* See page 59 for list of electives.
## B.S. in Electrical Engineering Curriculum

### FRESHMAN YEAR

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<th>Course and Description</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 113 — Digital Signal Processing</td>
<td>4</td>
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<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 115A — Analog Electronic Circuits I</td>
<td>4</td>
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<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 131A — Probability and Statistics</td>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering 101A — Engineering Electromagnetics</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering 115AL — Analog Electronics Laboratory I</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
<td>4</td>
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<tr>
<td>2nd Quarter</td>
<td>HSSEAS GE Elective*</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 101B (Electromagnetic Waves) or Computer Science 33 (Introduction to Computer Organization)</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 132A — Introduction to Communication Systems</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 133A — Mathematics of Design</td>
<td>4</td>
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<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering 141 — Principles of Feedback Control</td>
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### SENIOR YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course and Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 170A — Principles of Photonics</td>
<td>4</td>
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<tr>
<td>1st Quarter</td>
<td>Electrical Engineering Design Course</td>
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</tr>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering Elective</td>
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</tr>
<tr>
<td>2nd Quarter</td>
<td>Technical Breadth Course*</td>
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</tr>
<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering Design Course</td>
<td>4</td>
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<tr>
<td>2nd Quarter</td>
<td>Electrical Engineering Elective</td>
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<tr>
<td>2nd Quarter</td>
<td>HSSEAS GE Elective*</td>
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<tr>
<td>2nd Quarter</td>
<td>Technical Breadth Course*</td>
<td>4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Electrical Engineering or Computer Science Elective</td>
<td>4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>HSSEAS GE Elective*</td>
<td>5</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Technical Breadth Course*</td>
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</table>

**TOTAL** 187 or 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 21 for details).
# B.S. in Materials Engineering Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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</tr>
<tr>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<tr>
<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<tr>
<td>Materials Science and Engineering 10 — Freshman Seminar: New Materials</td>
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<tr>
<td>Mathematics 31A — Differential and Integral Calculus</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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</tr>
<tr>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
<td>7</td>
</tr>
<tr>
<td>Mathematics 31B — Integration and Infinite Series</td>
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<tr>
<td>Physics 1A — Mechanics</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Materials Science and Engineering 90L — Physical Measurement in Materials Engineering</td>
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<tr>
<td>Mathematics 32A — Calculus of Several Variables</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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</tr>
<tr>
<td>HSSEAS GE Elective*</td>
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<table>
<thead>
<tr>
<th>SOPHOMORE YEAR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Civil and Environmental Engineering 101 (Statics and Dynamics) or Mechanical and Aerospace Engineering 101 (Statics and Stress Analysis)</td>
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<tr>
<td>Mathematics 32B — Calculus of Several Variables</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
<td>5</td>
</tr>
<tr>
<td>HSSEAS GE Elective*</td>
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</tr>
<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<tr>
<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
<td>4</td>
</tr>
<tr>
<td>Mathematics 33A — Linear Algebra and Applications</td>
<td>4</td>
</tr>
<tr>
<td>HSSEAS GE Elective*</td>
<td>5</td>
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</tbody>
</table>

| **3rd Quarter**                  |       |
| Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I) | 4     |
| Mathematics 33B — Differential Equations                                   | 4     |
| HSSEAS Ethics Course                                                      | 4     |
| Technical Breadth Course*                                                  | 4     |

<table>
<thead>
<tr>
<th>JUNIOR YEAR</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids</td>
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<tr>
<td>Materials Science and Engineering 110/110L — Introduction to Materials Characterization A/Laboratory</td>
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<tr>
<td>Materials Science and Engineering 150 — Phase Relations in Solids</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Materials Science and Engineering 120 — Physics of Materials</td>
<td>4</td>
</tr>
<tr>
<td>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
<td>6</td>
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<tr>
<td>Materials Science and Engineering 143A — Mechanical Behavior of Materials</td>
<td>4</td>
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<tr>
<td>Technical Breadth Course*</td>
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</table>

| **3rd Quarter**                  |       |
| Materials Science and Engineering 132 — Structure and Properties of Metallic Alloys | 4     |
| Materials Engineering Electives (2)*                                      | 8     |
| Technical Breadth Course*                                                 | 4     |

<table>
<thead>
<tr>
<th>SENIOR YEAR</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
<td></td>
</tr>
<tr>
<td>Electrical Engineering 100 — Electrical and Electronic Circuits</td>
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<tr>
<td>Materials Science and Engineering 160 — Introduction to Ceramics and Glasses</td>
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<tr>
<td>Mechanical and Aerospace Engineering 181A (Complex Analysis and Integral Transforms) or 182A (Mathematics of Engineering)</td>
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<tr>
<td>Materials Engineering Elective*</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Materials Science and Engineering 150 — Introduction to Polymers</td>
<td>4</td>
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<tr>
<td>HSSEAS GE Elective*</td>
<td>5</td>
</tr>
<tr>
<td>Materials Engineering Elective*</td>
<td>4</td>
</tr>
<tr>
<td>Materials Engineering Laboratory Course*</td>
<td>2</td>
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</table>

| **3rd Quarter**                  |       |
| Materials Science and Engineering 140 — Materials Selection and Engineering Design | 4     |
| HSSEAS GE Elective*                                                         | 5     |
| Materials Engineering Laboratory Course*                                   | 2     |
| Technical Breadth Course*                                                  | 4     |

**TOTAL** 186

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† See counselor in 6426 Boelter Hall for details.
## B.S. in Materials Engineering
### Electronic Materials Option Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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<td>Materials Science and Engineering 10 — Freshman Seminar: New Materials</td>
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<tr>
<td></td>
<td>Mathematics 31A — Differential and Integral Calculus</td>
<td>4</td>
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<tr>
<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<tr>
<td></td>
<td>Mathematics 31B — Integration and Infinite Series</td>
<td>5</td>
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<tr>
<td></td>
<td>Physics 1A — Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Materials Science and Engineering 90L — Physical Measurement in Materials Engineering</td>
<td>2</td>
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<tr>
<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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<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Materials Science and Engineering 104 — Science of Engineering Materials</td>
<td>4</td>
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<tr>
<td></td>
<td>Mathematics 32B — Calculus of Several Variables</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials</td>
<td>4</td>
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<tr>
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<td>HSSEAS GE Elective*</td>
<td>5</td>
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<tr>
<td>2nd Quarter</td>
<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)</td>
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<tr>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td></td>
<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<tr>
<td></td>
<td>HSSEAS GE Elective*</td>
<td>5</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)</td>
<td>4</td>
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<tr>
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<td>Mathematics 33B — Differential Equations</td>
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<td>HSSEAS Ethics Course</td>
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<td>HSSEAS GE Elective*</td>
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### JUNIOR YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<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>2nd Quarter</td>
<td>Electrical Engineering 101A — Engineering Electromagnetics</td>
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<tr>
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<td>Materials Science and Engineering 120 (Physics of Materials) or Electrical Engineering 2 (Physics for Electrical Engineers)</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 122 — Principles of Electronic Materials Processing</td>
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<td>Materials Science and Engineering 131/131L — Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<tr>
<td>3rd Quarter</td>
<td>Materials Science and Engineering 121/121L — Materials Science of Semiconductors/Laboratory</td>
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<td>Electronic Materials Elective†</td>
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<td>Technical Breadth Course*</td>
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### SENIOR YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Course Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Electrical Engineering 121B — Principles of Semiconductor Device Design</td>
<td>4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 181A (Complex Analysis and Integral Transforms) or 182A (Mathematics of Engineering)</td>
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<td>Electronic Materials Elective†</td>
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<tr>
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<td>Technical Breadth Course*</td>
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<tr>
<td>2nd Quarter</td>
<td>Electronic Materials Elective†</td>
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<tr>
<td></td>
<td>Electronic Materials Laboratory Course†</td>
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<tr>
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<td>HSSEAS GE Elective*</td>
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<tr>
<td></td>
<td>Technical Breadth Course*</td>
<td>4</td>
</tr>
<tr>
<td>3rd Quarter</td>
<td>Materials Science and Engineering 140 — Materials Selection and Engineering Design</td>
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<tr>
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<td>Electronic Materials Electives (2)†</td>
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</tr>
<tr>
<td></td>
<td>Electronic Materials Laboratory Course†</td>
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</tbody>
</table>

**TOTAL** 188

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† See counselor in 6426 Boelter Hall for details.
## B.S. in Mechanical Engineering Curriculum

### Freshman Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td></td>
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</tbody>
</table>
Chemistry and Biochemistry 20A — Chemical Structure | 4 |
English Composition 3 — English Composition, Rhetoric, and Language | 5 |
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 | 
Mathematics 32A — Calculus of Several Variables | 4 |
Physics 1B — Oscillations, Waves, Electric and Magnetic Fields | 5 |
Physics 4AL — Mechanics Laboratory | 2 |
HSSEAS GE Elective* | 5 |

### Sophomore Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Units</th>
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<tbody>
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<td>1st Quarter</td>
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</tbody>
</table>
Mathematics 32B — Calculus of Several Variables | 4 |
Mechanical and Aerospace Engineering 94 — Introduction to Computer-Aided Design and Drafting | 4 |
Physics 1C — Electrodynamics, Optics, and Special Relativity | 5 |
Physics 4BL — Electricity and Magnetism Laboratory | 2 |
| 2nd Quarter | 
Materials Science and Engineering 104 — Science of Engineering Materials | 4 |
Mathematics 33A — Linear Algebra and Applications | 4 |
Mechanical and Aerospace Engineering 101 — Statics and Strength of Materials | 4 |
Mechanical and Aerospace Engineering 105A — Introduction to Engineering Thermodynamics | 4 |
| 3rd Quarter | 
Mathematics 33B — Differential Equations | 4 |
Mechanical and Aerospace Engineering 162A — Introduction to Mechanisms and Mechanical Systems | 4 |
Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I) | 4 |
Mechanical and Aerospace Engineering 102 — Dynamics of Particles and Rigid Bodies | 4 |
Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics | 4 |

### Junior Year

<table>
<thead>
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<th>Quarter</th>
<th>Units</th>
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<tbody>
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</table>
Electrical Engineering 100 — Electrical and Electronic Circuits | 4 |
Mechanical and Aerospace Engineering 105D — Transport Phenomena | 4 |
Mechanical and Aerospace Engineering 182A — Mathematics of Engineering | 4 |
Mechanical and Aerospace Engineering 183 — Introduction to Manufacturing Processes | 4 |
| 2nd Quarter | 
Mechanical and Aerospace Engineering 107 — Introduction to Modeling and Analysis of Dynamic Systems | 4 |
HSSEAS Ethics Course | 4 |
HSSEAS GE Elective* | 5 |
Technical Breadth Course* | 4 |
| 3rd Quarter | 
Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics) | 4 |
Mechanical and Aerospace Engineering 157 — Basic Mechanical Engineering Laboratory | 4 |
Mechanical and Aerospace Engineering 162A — Introduction to Mechanisms and Mechanical Systems | 4 |
Technical Breadth Course* | 4 |

### Senior Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td></td>
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</tbody>
</table>
Electrical Engineering 110L — Circuit Measurements Laboratory | 2 |
Mechanical and Aerospace Engineering 156A — Advanced Strength of Materials | 4 |
Mechanical and Aerospace Engineering 171A — Introduction to Feedback and Control Systems | 4 |
Technical Breadth Course* | 4 |
| 2nd Quarter | 
Mechanical and Aerospace Engineering 162D — Mechanical Engineering Design I | 4 |
HSSEAS GE Electives (2*) | 10 |
Mechanical Engineering Elective | 4 |
| 3rd Quarter | 
Mechanical and Aerospace Engineering 162E — Mechanical Engineering Design II | 4 |
HSSEAS GE Elective* | 5 |
Mechanical Engineering Elective | 4 |

**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 21 for details).
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