ANNOUNCEMENT 2018-19

HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE

UNIVERSITY OF CALIFORNIA, LOS ANGELES
OCTOBER 1, 2018
As a matter of practice, UCLA does not publish student 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.

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 Student Conduct, 1104 Murphy Hall.

A copy of the federal and state laws, University policies, and the print UCLA Telephone Directory may be obtained from that office and from the Office of Student Conduct, 1104 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.
A Message from the Dean

The UCLA Henry Samueli School of Engineering and Applied Science has a long legacy of excellence in research, education, and service to society.

Great challenges lie ahead! Engineers seek to improve society and better the lives of many. In the twenty-first century this includes fostering a more sustainable planet, developing new medicines and health care technologies, and finding hidden insights from a deluge of data. A new generation of engineers is needed to tackle these complex problems. At UCLA we are proud to teach students who are creative, brilliant, and bring an exemplary work ethic to their studies.

The school offers a rigorous curriculum designed to prepare students for careers in industry. Many of our graduates use their engineering education to pursue other professions, become entrepreneurs, or enter a career in academia. Our classes are taught by faculty members who are among the best in the world in their respective fields.

And beyond just engineering, UCLA is a vibrant campus unlike any other. For nearly a century, this University has been home to daring risk-takers and bold game-changers. From the arts and sciences to medicine and here in engineering, UCLA has always been at the forefront.

For our prospective students, let me offer three points beyond the curriculum on what this great University offers.

First, you will meet some extraordinary people in your fellow students. In engineering and the sciences and in the humanities and arts, the talent, smarts, outside-the-box thinking, and collaborative can-do energy at UCLA are unparalleled.

Second, UCLA isn’t just a great university in isolation. It is an integral part of one of the world’s great cities. Los Angeles is a tech capital. World-leading firms in aerospace and defense, semiconductors, biotechnology, and other areas are headquartered in Southern California or have a major presence here. The region also has a major startup scene in which so many UCLA engineers play a part. Los Angeles sets the agenda in design, arts and entertainment, sustainability, the environment, and more.

Third, there are amazing research opportunities for undergraduate students here. Our faculty members are world leaders in their fields, and undergraduate students are a part of many of their laboratories. Some of our students collaborate with the medical school and leaders in other disciplines as they pursue new knowledge.

Finally, UCLA Samueli is entering an extraordinary period of growth with significant expansion in the number of faculty members and students. The school already is world-renowned, but we are reaching for new heights. With this growth will come extraordinary new opportunities for our students to have significant impact on our society and the world.

This is a truly exciting time to study at UCLA Samueli. I invite you to be part of it.

Jayathi Y. Murthy
Ronald and Valerie Sugar Dean of UCLA Engineering
Henry Samueli School of Engineering and Applied Science

Officers of Administration

Jayathi Y. Murthy, Ph.D., Professor and Dean, Henry Samueli School of Engineering and Applied Science
Scott J. Brandenberg, Ph.D., Professor and Associate Dean, Diversity and Inclusion
Jia-Ming Liu, Ph.D., Professor and Associate Dean, Academic Personnel
Harold G. Monbouquette, 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
Panagiotis D. Christofides, Ph.D., Professor and Chair, Chemical and Biomolecular Engineering Department
Adrian Y. Darwiche, Ph.D., Professor and Chair, Computer Science Department
Bruce S. Dunn, Ph.D., Professor and Chair, Materials Science and Engineering Department
Timothy S. Fisher, Ph.D., Professor and Chair, Mechanical and Aerospace Engineering Department
Song Li, Ph.D., Professor and Chair, Bioengineering Department
Gregory J. Pottie, Ph.D., Professor and Chair, Electrical and Computer Engineering Department
Ertugrul Tacioglu, Ph.D., Professor and Chair, Civil and Environmental Engineering Department

Ronald Reagan UCLA Medical Center for treatment. The university's 419-acre campus houses the College of Letters and Science and 12 professional schools. There are over 45,000 students enrolled in 134 undergraduate and 258 graduate degree programs. UCLA is rated one of the best public research universities in the U.S. and among a handful of top U.S. research universities, public and private. The chief executive of UCLA is Chancellor Gene D. Block. He oversees all aspects of the university's three-part mission of education, research, and service.

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

The School

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

UCLA engineering faculty members are active participants in many interdisciplinary research centers. The Synthetic Control Across Length-Scales for Advancing Rechargeables (SCALAR) Center is exploring new types of chemistry and materials for rechargeable batteries.

The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) strives to revolutionize development of consumer electronics by engineering materials that optimize energy efficiency, size, and power output on the small scale. The Focus Center on Function Accelerated nanoMaterial Engineering (FAME) aims to revolutionize semiconductor technologies by developing new nanoscale materials and structures that take advantage of properties unavailable at larger scales. The WIN Institute of Neurotronics (WINs) focuses on cutting-edge technologies, including nanostructures. The Center of Excellence for Green Nanotechnologies undertakes frontier research and development in the areas of nanotechnology in energy and nanoelectronics. The Center for Domain-Specific Computing (CDSN) 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 health care 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.

The California NanoSystems Institute (CNSI)—a joint endeavor with UC Santa Barbara—develops the information, biomedical, and manufacturing technologies of the twenty-first century.

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

And the school has established the Institute for Technology Advancement (ITA) dedicated to the effective transition of high-impact innovative research from UCLA to product development and commercialization.

The school offers 40 academic and professional degree programs. The Bachelor of Science degree is offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer 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 founda-
tion 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. The schoolwide online Master of Science in Engineering degree program includes 11 individual degrees. 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 25. 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
- Vijay K. Dhir Chair in Engineering
- Englekirk Presidential Endowed Chair in Structural Engineering
- Traugott and Dorothea Frederking Endowed Chair in Cryogenics
- Norman E. Friedmann Chair in Knowledge Sciences
- Armond and Elena Hairapetian Chair in Engineering and Medicine
- Leonard Kleinrock Chair in Computer Science
- Evalyn 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
Ben Rich Lockheed Martin Chair in Aeronautics
Rockwell Collins Chair in Engineering
John P. and Claudia H. Schauerman Endowed Chair in Engineering
William Frederick Seyer Chair in Materials Electrochemistry
Ronald and Valerie Sugar Endowed Chair in Engineering
Symantec Term Chair in Computer Science
Carol and Lawrence E. Tannas, Jr., Endowed Chair in Engineering
Carol and Lawrence E. Tannas, Jr., Endowed Term Chair in Engineering
William D. Van Vorst Chair in Chemical Engineering Education
Volgenau Chair for Engineering Excellence
Volgenau Chair for Engineering Innovation
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, systems engineering, biotechnology and biomolecular engineering, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, biotechnology, biofuel, food, aerospace, automotive, water treatment, and semiconductor industries. Architectural, engineering, and construction firms employ chemical engineers for equipment and process design. It is also their mission to develop the clean and environmentally friendly technologies of the future.
Major areas of fundamental interest within chemical engineering are

1. **Applied chemical kinetics**, which involves the design of chemical and biochemical reactors and processes and the creation of catalysts that accelerate reaction kinetics and modeling.

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

3. **Thermodynamics**, which is fundamental to physical, chemical, and biological processes, and

4. **Process design and synthesis**, which provide the overall framework and computing technology for integrating chemical engineering knowledge into industrial application and practice.

Civil and Environmental Engineering

Civil engineers plan, design, construct, and manage a range of physical systems, such as buildings, bridges, dams and tunnels, transportation systems, water and wastewater treatment systems, coastal and ocean engineering facilities, and environmental engineering projects, related to public works and private enterprises. Thus, civil and environmental engineering embraces activities in traditional areas and in emerging problem areas associated with modern industrial and social development.

The civil engineering profession demands rigorous scientific training and a capacity for creativity and growth into developing fields. In Southern California, besides employment in civil engineering firms and governmental agencies for public works, civil engineering graduates often choose other industries for assignments based on their engineering background. Graduates are also qualified for positions outside engineering where their broad engineering education is a valuable asset.

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

Computer Science and Engineering

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

Undergraduate students can major in the computer science and engineering program, the computer science program, or the computer engineering 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 and Computer Engineering

The electrical and computer engineering discipline is concerned with the useful applications of electromagnetic phenomena (light, magnetism, electricity). Courses and research at UCLA span the entire stack from basic physics, electronic and photonic devices, antennas, integrated circuits, signal processing and machine learning, control, communications systems, to vast networks such as the electrical grid and the Internet. These are the main automated tools used by our society to sense, make decisions, and take action in the world using the data collected according to the priorities established by people. The Electrical and Computer 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 and computer 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 pro-
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.

**Academic Calendar**

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2018</th>
<th>Winter 2019</th>
<th>Spring 2019</th>
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<tbody>
<tr>
<td>First day for continuing students to check MyUCLA at <a href="http://my.ucla.edu">http://my.ucla.edu</a> for assigned enrollment appointments</td>
<td>May 29</td>
<td>October 29</td>
<td>January 28</td>
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<tr>
<td>MyUCLA enrollment appointments begin</td>
<td>June 18</td>
<td>November 5</td>
<td>February 11</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 24</td>
<td>January 2, 2019</td>
<td>March 27</td>
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<tr>
<td>Instruction begins</td>
<td>September 27</td>
<td>January 7</td>
<td>April 1</td>
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<tr>
<td>Last day for undergraduates to add courses with per-course fee through MyUCLA</td>
<td>October 19</td>
<td>January 25</td>
<td>April 19</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 26</td>
<td>February 1</td>
<td>April 26</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 9</td>
<td>February 15</td>
<td>May 10</td>
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<tr>
<td>Instruction ends</td>
<td>December 7</td>
<td>March 15</td>
<td>June 7</td>
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<tr>
<td>Final examinations</td>
<td>December 10–14</td>
<td>March 18–22</td>
<td>June 10–14</td>
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<tr>
<td>Quarter ends</td>
<td>December 14</td>
<td>March 22</td>
<td>June 14</td>
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<tr>
<td>Engineering Commencement</td>
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<td>June 15</td>
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<tr>
<td>Academic and administrative holidays</td>
<td>November 9</td>
<td>January 21</td>
<td>March 29</td>
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<tr>
<td>Academic and administrative holidays</td>
<td>November 22-23</td>
<td>February 18</td>
<td>May 27</td>
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<tr>
<td>Winter campus closure (tentative)</td>
<td>December 31,</td>
<td>January 1</td>
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<tr>
<td>Dates subject to change; see UCLA Registrar's Office website for most current information.</td>
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**Admission Calendar**

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2018</th>
<th>Winter 2019</th>
<th>Spring 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filing period for undergraduate applications (file online at <a href="http://admission.universityofcalifornia.edu/how-to-apply/apply-online/index.html">http://admission.universityofcalifornia.edu/how-to-apply/apply-online/index.html</a>)</td>
<td>November 1–30, 2017</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Last day to file Application for Graduate Admission or readmission with complete credentials and application fee, online at <a href="https://app.applyyourself.com/AYApplicantLogin/l_ApplicantConnectLogin.asp?id=ucla-grad">https://app.applyyourself.com/AYApplicantLogin/l_ApplicantConnectLogin.asp?id=ucla-grad</a> or with Graduate Diversity, Inclusion, and Admissions (DIA), 1248 Murphy Hall, UCLA, Los Angeles, CA 90024-1419</td>
<td>Consult department</td>
<td>Consult department</td>
<td>Consult department</td>
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<tr>
<td>Last day to file Undergraduate Readmission Application 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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</tbody>
</table>
## Correspondence Directory

**Henry Samueli School of Engineering and Applied Science**
https://samueli.ucla.edu

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

**Bioengineering Department**
5121 Engineering V
https://www.bioeng.ucla.edu

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

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

**Computer Science Department**
277 Engineering VI
https://www.cs.ucla.edu

**Electrical and Computer Engineering Department**
58-121 Engineering IV
https://www.ee.ucla.edu

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

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

**Continuing Education in Engineering**
UCLA Extension
10960 Wilshire Boulevard, Suite 1600
https://www.uclaextension.edu/engineering

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

**Master of Science in Engineering Online Program**
4732 Boelter Hall
https://www.msol.ucla.edu

### Academic Counselors

#### Aerospace Engineering
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**Bioengineering**
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**Undeclared Engineering**
Erkki Corpuz, 310-825-9442, erkki@seas.ucla.edu; Jan J. LaBuda, 310-825-2514, jan@seas.ucla.edu

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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
https://grad.ucla.edu/gasaa/admissions/

**Financial Aid and Scholarships**
A129J Murphy Hall
https://www.financialaid.ucla.edu

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

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

**Summer Sessions**
1332 Murphy Hall
https://www.summer.ucla.edu

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

Facilities and Services

Teaching and research facilities at UCLA Samueli are in Boelter Hall, Engineering IV, Engineering V, and Engineering VI, located in the southern part of the UCLA campus. Boelter Hall houses classrooms and laboratories for undergraduate and graduate instruction, the Office of Academic and Student Affairs (http://www.seasoasa.ucla.edu), the SEASnet computing facility (http://www.seas.ucla.edu/ceasnet/), specialized libraries, offices of faculty and administration, Shop Services Center, and the Student and Faculty Shop. The California NanoSystems Institute (CNSI) building hosts additional school 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 12 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 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 tens of thousands of e-books. The library offers access to online databases covering each discipline. The SEL/Boelter location (formerly 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 offers laptop checkout, a group study room, two spaces for collaborative group work (the Learning Commons and the Research Commons), and quiet areas for study.

The SEL/Geology location, 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, http://www.library.ucla.edu/selection, is the access point to all of the above resources. The site also supplies information on course reserves, laptop lending, interlibrary loan, document delivery, news and events, 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

Computing Resources
Nicodemus Wibowo, SEASnet Director
UCLA Samueli maintains an advanced computing facility and local-area network to support its education, research, and administrative activities. A total of 16 full-time positions and 30 lab consultants support the school's computing needs.

A network of over 158 enterprise servers supplies a wide array of critical services. Eight Network Appliance NFS servers supply reliable storage for users' personal data and e-mail, and offer nearly instant recovery of deleted files through regular snapshots.

More than 100 Unix/Linux servers, including 20 virtual machines, supply both administrative and instructional support to ensure smooth operation of approximately 700 Linux and Windows workstations. The Unix servers handle back-end services such as DNS, authentication, virtualization, software licensing, web servers, interactive login, database, e-mail, class applications, and security monitoring.

Thirty Windows servers make up the backbone for all instructional computing labs, and allow students to work remotely with resource- and computationally intensive applications. There are four computer labs and one instructional computer lab with 200 Windows workstations.

A high-speed network that links the entire infrastructure enables faculty to access the UCLA and around the world. It consists of dual fiber uplinks to a Cisco core router, which feeds and routes 20 networks and over 150 switches. 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. Tapes are sent to off-site storage monthly.

The servers are protected by two high-capacity UPS units along with seven racked UPS for short-term power outages. Campus emergency power keeps critical equipment running during extended downtime.

Students and faculty have access to retail Microsoft software, through the Microsoft Developer Network Academic Alliance (MS DNAA) program; MathType software; and Abaqus, through a download service at no charge. Faculty and staff have access to Microsoft Office software at no charge through the same service and the Microsoft Consolidated Campus Agreement (MCCA). Adobe software is also available to tenure-track faculty and staff. Microsoft Imagine Premium, Autodesk, and Ansys programs offer additional software at no charge to all UCLA engineering students.

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, Windows, and Macintosh workstations. The school is connected to the Internet through high-speed networks. Computing resources at the national supercomputer centers are also available.

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

Continuing Education

UCLA Extension
10960 Wilshire Boulevard, Suite 1600
Department of Engineering
Varaz Shahnian, Ph.D., Director
Vivian Taslakian, M.B.A., Program Director
Department of Digital Technology
Bruce Huang, Ph.D., Director

The UCLA Extension Engineering and Digital Technology departments offer 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. The acclaimed Technical Management Program has been offered for more than 60 years.

The Information Systems program offers over 200 courses annually in applications programming, database management, information systems, security, Unix/Linux, operating systems, systems analysis, data science, and Web technology.
The engineering program offers over 250 courses annually, including 10 certificate programs in advanced plumbing systems design, biotechnology engineering, communication systems, construction management, contract management, information technology management, government cost estimating and pricing, medical device engineering, recycling and solid waste management, and supply chain management. In addition, the department offers EIT and PE review courses in mechanical engineering. Most engineering and technical management courses are offered evenings on the UCLA campus, or are available online. See https://www.uclaextension.edu/engineering.

Career Services
UCLA Career Center
501 Westwood Plaza, Strathmore Building
310-206-1915
https://career.ucla.edu

Erin Haywood, Engineering Undergraduate Counselor, ehaywood@career.ucla.edu

David Blancha, Assistant Director, Graduate Student Services, ddblancha@career.ucla.edu

The UCLA Career Center assists UCLA Samueli undergraduates and graduates, 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 education and counseling; skill, values, personality, and interest assessments; workshops; industry-specific programming; employer information sessions; career fairs; targeted networking opportunities; and drop-in counseling. Annual engineering and technical fairs, held in fall and winter quarters, feature more than 100 top national and local employers. Students can discover internship and job opportunities, access career resources, and register for events through Handshake.

The Career Center is open Monday through Friday from 9 a.m. to 5 p.m. Drop-in counseling is available Tuesday through Thursday from 10 a.m. to 2 p.m.; engineering-specific drop-ins are available Thursday from 12:30 to 2:30 p.m. in 6288 Boelter Hall. Counseling appointments are scheduled through Handshake.

Health Services
Ashe Student Health and Wellness Center
221 Westwood Plaza
310-825-4073
http://www.studenthealth.ucla.edu

The Ashe Student Health and Wellness Center is a full-service medical clinic available to all registered UCLA students. Most services are subsidized by registration fees, and a current BruinCard is required for service. 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, laboratory, and optometry and radiology sections. Visits, core laboratory tests, X-rays, and preventive immunizations are all prepaid for students with the University of California Student Health Insurance Plan (UCSHIP).

The cost of services received outside the Ashe Center, such as emergency room services, is each student's financial responsibility. Students are required to purchase medical insurance either through the UCLA-sponsored UCShiP or other plans that provide adequate coverage. Adequate medical insurance is a condition of registration.

Consult the Ashe Center website for specific information on its primary care, women's health, immunization, health clearance, optometry, travel medicine, and mind-body clinics, as well as on dental care available to students at discounted rates.

For emergency care when the Ashe Center is closed, students may obtain treatment at the Ronald Reagan UCLA Medical Center Emergency Room on a fee-for-service basis.

For specific UCShiP benefits tier structure and coverage information, see the Ashe Center website and select Insurance or send e-mail to shsinsurance@ashe.ucla.edu.

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 asheimmune@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 withdraws during a term continues to be eligible for health services for the remainder of the term on a fee basis.

The Ashe Center is open Monday through Friday during the academic year.

Services for Students with Disabilities
Center for Accessible Education
A255 Murphy Hall
voice 310-825-1501, TTY 310-206-6083
https://www.cae.ucla.edu

The Center for Accessible Education (CAE) 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. CAE policies and practices comply with all applicable federal and state laws, including Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (ADA) of 1990, and are consistent with University policy.

Services include campus orientation and accessibility, note takers, reader service, sign language interpreters, Learning Disability Program, registration assistance, test-taking facilitation, special parking assistance, real-time captioning, assistive listening devices, on-campus transportation, adaptive equipment, support groups and workshops, tutorial referral, special materials, housing appeals, referral to the UCLA 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.

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

The Dashew Center for International Students and Scholars assists students with questions about immigration, employment, government regulations, financial aid, academic and administrative procedures, cultural adjustment, and personal matters. The center seeks to improve student and community relationships; helps international students with language, housing, and personal concerns; and sponsors cultural, educational, and social programs. It also offers visa assistance for faculty members, researchers, and postdoctoral scholars.

Fees and Financial Support

Fees and Expenses

Annual UCLA student fees shown for 2018-19 are current as of publication. See the Reg-
istrar’s Office fees web page for fees breakdown by term at https://sa.ucla.edu/RO/Fees/Public/public-fees.

Students who are not legal residents of California (out-of-state and international students) pay nonresident supplemental tuition. See the UCLA General Catalog appendix or the Registrar’s website residence section at https://www.registrar.ucla.edu/Fees-Residence-Requirements for information on how to determine residence for tuition purposes. Further inquiries may be directed to the Residence Deputy, 1113 Murphy Hall, UCLA, Los Angeles, CA 90024-1429.

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

Living Accommodations

UCLA Housing Services
360 De Neve Drive, Box 951383
Los Angeles, CA 90095-1383
310-206-7011
https://housing.ucla.edu

Housing in Los Angeles, both on and off campus, is in great demand. Students should make arrangements early. Newly admitted students should access the UCLA Housing website for information about costs, locations, and eligibility for both private and UCLA-sponsored housing.

Information about campus residence halls and suites is available from UCLA Housing Services.

Financial Aid

Financial Aid and Scholarships
A129J Murphy Hall
310-206-0400
https://www.financialaid.ucla.edu

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 2019-20 academic year is March 2, 2019. With the exception of certain scholarships, awards are based on need as determined by national financial aid criteria. California residents must file the Free Application for Federal Student Aid (FAFSA).

International students in their first year are ineligible for aid. Continuing undergraduate international students are asked to submit a separate Financial Aid Application for International Students.

Scholarships

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

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

UCLA Samueli 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 2017-18, the school awarded 159 undergraduate scholarships totaling more than $723,000. The majority of these scholarships are publicized in the fall, with additional scholarships promoted throughout the aca-

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<thead>
<tr>
<th>2018-19 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES</th>
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<tbody>
<tr>
<td>Fees are subject to revision without notice.</td>
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<tr>
<td><strong>Undergraduate Students</strong></td>
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<tr>
<td><strong>Tuition</strong></td>
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<tr>
<td>Resident</td>
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<td>11,442.00</td>
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<tr>
<td><strong>Student Services Fee</strong></td>
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<td>$1,128.00</td>
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<td><strong>Nonresident Supplemental Tuition (NRST)</strong></td>
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<td>$28,992.00</td>
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<td><strong>Ackerman Student Union Fee</strong></td>
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<td>66.00</td>
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<td><strong>Ackerman/Kerckhoff Seismic Fee</strong></td>
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<td>113.00</td>
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<td><strong>Arts Restoring Community Fee</strong></td>
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<td><strong>Bruin Bash Fee</strong></td>
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<tr>
<td><strong>Course Materials and Services Fee</strong></td>
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<td>varies, see course listings</td>
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<tr>
<td><strong>Graduate Students Association Fee</strong></td>
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<td>38.25</td>
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<tr>
<td><strong>Graduate Writing Center Fee</strong></td>
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<tr>
<td><strong>Green Initiative Fee</strong></td>
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<td><strong>Instructional Enhancement Initiative (IEI) Fee</strong></td>
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<td><strong>PLEDGE Fee</strong></td>
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<td><strong>Student Programs, Activities, and Resources Complex (SPARC) Fee</strong></td>
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<td><strong>Undergraduate Students Association Fee</strong></td>
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<td><strong>Wooden Center Fee</strong></td>
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<tr>
<td><strong>Continuing student total mandatory fees</strong></td>
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<tr>
<td>$15,775.42</td>
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<tr>
<td><strong>New student total mandatory fees</strong></td>
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<td>$15,940.42</td>
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*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.
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 UCLA Samueli 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 supply 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 UCLA Samueli in order to be considered in the 2018-19 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 the school, the University also offers work-study and low-interest loans based on financial need exclusively.

Need-based awards are administered by Financial Aid and Scholarships, 1129 J. 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 2018 for information on 2019-20 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 the school 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 any engineering department.

William and Mary Beadle 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.

Boeing Fellowship. Supports graduate study in mechanical and aerospace engineering.

John J. and Clara C. Boelter Fellowship. Supports study in engineering.

Broadcom Fellowship. Electrical and Computer 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
Intel Fellowship. Computer Science Department; supports doctoral study in selected areas of computer science
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 Knesel 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 by an international student in structural mechanics
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 and Computer 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 from National Taiwan University, National Tsing Hua University, or National Chiao Tung University in Taiwan
Microsoft Fellowship. Supports doctoral study in computer science
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 Fellowship. Supports graduate study in mechanical and aerospace 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
Martin Rubin Scholarship. Supports two undergraduate and/or graduate students pursuing degrees in civil engineering with an interest in transportation engineering
Henry Samueli Fellowship. Electrical and Computer 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
Dr. Robert K. Williamson Graduate Fellowship. Supports graduate study in mechanical and aerospace 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 UCLA Samueli 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

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 80 students participated in SMASH during summer 2018.

MESA Schools Program (MSP). Through CEED, UCLA Samueli 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 1000 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. UCLA Samueli 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 335 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—Introduction to 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 engi-
neering 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.

**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-genera-

tion electromagnetic (EM) devices. Its goal is to create a synergistic environment that fos-
ters 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 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.

The 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 the 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 the Eidgenössische Technische Hochschule in Switzerland. 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**

UCLA Samueli also participates in the NACME and GEM scholarships. The CEED Industry Advisory Board and support network provide significant contributions to program services and scholarships. Information may be obtained from the CEED director.

**Student Organizations**

UCLA Samueli 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**

http://nsbebruins.wixsite.com/nsbe/home

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 pro-

CEED students participate in a professional development workshop.
vides 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.

**Society of Latino Engineers and Scientists**

http://www.uclasoles.com

Recognized as the national chapter of the year five times over the past ten years by the Society of Hispanic Professional Engineers (SHPE), SOLES promotes engineering as a viable career option for Latino students. SOLES is committed to the advancement of Latinos in engineering and science through endeavors to stimulate intellectual pursuit through group study, 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.

**Women in Engineering**

Women make up about 25 percent of the UCLA Samueli undergraduate enrollment and 22 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**

http://www.seas.ucla.edu/swe/

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.

**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 https://samueli.ucla.edu/student-clubs-organizations.

- **AAEA** Arab American Association of Engineers and Architects
- **ACM** Association for Computing Machinery
- **ACM-W** Association for Computing Machinery–Women
- **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/BattleBots
- **BEAM** Building Engineers and Mentors
- **BMES** Biomedical Engineering Society
- **BruinKSEA** Korean-American Scientists and Engineers Association
- **CalGeo** California Geotechnical Engineers Association
- **Chi Epsilon** Civil Engineering Honor Society
- **Eta Kappa Nu** Electrical engineering/computer science and engineering honor society

**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 UCLA Samueli annual commencement event, and their achievements are featured on the UCLA website and in the UCLA bulletin.
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 engineering 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.

Exceptional Student Admissions Program

http://www.seasosa.ucla.edu/exceptional-student-admissions-program/

The Harry Samueli School of Engineering and Applied Science has an Exceptional Student Admissions Program (ESAP) for its outstanding undergraduates who wish to enter the school graduate program upon completion of the BS degree. ESAP is an alternative to the Departmental Scholar Program. In contrast to that program, an ESAP admitted student would be an enrolled graduate student and would be eligible for consideration of graduate fellowships and teaching assistant positions if available.

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://catalog.registrar.ucla.edu), however, is the official and binding document for the guidance of students. UCLA students are responsible for complying with all rules, regulations, policies, and procedures described in the Catalog.

For rules and regulations on graduate study, see the Graduate Division website, https://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

A student who believes that a grade has been given unfairly 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 and harassment on any of the above bases. This nondiscrimination policy covers admission, access, and treatment in University programs and activities.

Students may grieve any action that they believe discriminates against them on the ground of race, color, national or ethnic origin, alienage, sex, religion, age, sexual orientation, gender identity, marital status, veteran status, or perceived membership in any of these categories which results in injury to the student by contacting the Office of the Dean of Students by e-mail at dean@saonet.ucla.edu, or in person at 1104 Murphy Hall. Refer to UCLA Procedure 230.1, available in 1104 Murphy Hall or at http://www.adminpolicies.ucla.edu/APP/Number/230.1, for more information and procedures.

Inquiries regarding University student-related nondiscrimination policies may be directed to the Office of the Dean of Students by e-mail at dean@saonet.ucla.edu, in person at 1104 Murphy Hall, or by phone at 310-825-3871. An assistant dean is available at this office to support students who need information or assistance in filing a discrimination complaint.

In accordance with applicable federal and state laws and University policy, including Title II of the Americans with Disabilities Act, Section 504 of the Rehabilitation Act of 1973, and University of California policy P4A0S-20 (Policy on Nondiscrimination), UCLA does not discriminate on the basis of physical or mental disability. Retaliation for participation in University procedures relating to complaints of discrimination is also prohibited. This nondiscrimination policy covers admission, access, and treatment in University programs and activities. UCLA is committed to prohibiting disability-based discrimination and harassment, and retaliation, performing a prompt and equitable investigation of complaints alleging discrimination, and properly remedying discrimination when it occurs. Examples of discrimination against students with disabilities include, but are not limited to: failure to engage with the student in a discussion of reasonable accommodations; failure to implement approved reasonable accommodations such as the provision of notes or extra time on tests; and exclusion of a qualified student from any course, course of study, or other educational program or activity because of the
Complaint Resolution
An individual who believes that they have been sexually harassed may contact the Title IX Coordinator, 2241 Murphy Hall, 310-206-3417, titleix@conet.ucla.edu. If a student reports sexual harassment or sexual violence to a responsible employee, as defined under the SVSH Policy, the responsible employee must report it to the Title IX Coordinator. Responsible employees include academic personnel, faculty members, and most other employees who are not defined as a confidential resource under the SVSH Policy.

Title IX prohibits sex discrimination, including sexual harassment and sexual violence, in any education program or activity receiving federal financial assistance. Inquiries regarding the application of Title IX may be directed to the Title IX Coordinator, 2241 Murphy Hall, 310-206-3417, titleix@conet.ucla.edu, or the U.S. Department of Education Office for Civil Rights at ocr@ed.gov.

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; https://www.ucop.edu/student-affairs/policies/student-life-policies/pacaos.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 the Policies.

Complaint Resolution
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 these Policies are available in the Office of Student Conduct, 1104 Murphy Hall.

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 the UC Policy on Sexual Violence and Sexual Harassment (hereafter referred to as the SVSH Policy) at http://policy.ucop.edu/doc/4000385/SVSH(PDF). 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 the SVSH Policy. See the Title IX office website at https://www.ssexualharassment.ucla.edu.

Definitions
For detailed definitions of sexual harassment, refer to the SVSH Policy.
Undergraduate Programs

The Henry Samueli School of Engineering and Applied Science offers 10 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
2. Bachelor of Science in Bioengineering
3. Bachelor of Science in Chemical Engineering
4. Bachelor of Science in Civil Engineering
5. Bachelor of Science in Computer Engineering
6. Bachelor of Science in Computer Science
7. Bachelor of Science in Computer Science and Engineering
8. Bachelor of Science in Electrical Engineering
9. Bachelor of Science in Materials Engineering
10. Bachelor of Science in Mechanical Engineering

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.computer.org. The undergraduate program in computer engineering, established in fall 2017, will be submitted to ABET for accreditation during the next ABET visit in 2024.

Admission

Admission to UCLA Samueli must satisfy the general UC admission requirements. See the Undergraduate Admission website at http://www.admission.ucla.edu for details. Applicants must apply directly to the school 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 the ACT with Writing tests, the SAT Reasoning Test (last administered January 2016), or the SAT with Essay 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.

Admission as a Freshman

UC 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 UCLA Samueli.

Freshman applicants must meet the UC 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 2018 fulfills UCLA Samueli requirements as indicated on the AP credit table.

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 of California 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 UCLA Samueli majors must have at least a 3.4 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 UCLA Samueli 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 UCLA Samueli majors:

1. Mathematics, including calculus I and II, calculus III (multivariable), differential equations, and linear algebra. The Aerospace Engineering and Mechanical Engineering majors do not require differential equations, but it is recommended
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. Bioengineering and Chemical Engineering majors are also required to complete two terms of organic chemistry. The Computer Science and Computer Science and Engineering majors do not require chemistry. Electrical Engineering majors must complete only one term of chemistry
4. Computer programming: applicants to the Computer Science, Computer Science and Engineering, and Electrical Engineering majors may take any C++, C, or Java course to meet the admission require-
Henry Samueli School of Engineering and Applied Science
Advanced Placement (AP) 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>3, 4, or 5</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</td>
<td>3, 4, or 5</td>
<td>4 units (may be applied toward Chemistry 20A) plus 4 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>Computer Science (AB Test)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Computer Science Principles</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macroeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>Economics 2 (4 excess units)</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>Microeconomics</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>Economics 1 (4 excess units)</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
<td></td>
</tr>
<tr>
<td>Literature and Composition</td>
<td>3</td>
<td>8 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
</tr>
<tr>
<td>4 or 5</td>
<td>English Composition 3 (5 units) plus 3 excess units</td>
<td>Satisfies Entry-Level Writing Requirement</td>
<td></td>
</tr>
<tr>
<td>Environmental Science</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Geography, Human</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Government and Politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparative</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>4 or 5</td>
<td>8 excess units</td>
<td>No application</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>Satisfies American History and Institutions Requirement</td>
</tr>
<tr>
<td>Subject</td>
<td>Requirement</td>
<td>Units</td>
<td>Application</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------------</td>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>World</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Languages and Literatures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Language</td>
<td>3</td>
<td>French 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>French 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>French 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>French Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>German Language</td>
<td>3</td>
<td>German 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>German 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>German 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Japanese Language and Culture</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Latin</td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Latin Literature</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Vergil</td>
<td>3</td>
<td>Latin 1 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Latin 3 (4 units)</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Language</td>
<td>3</td>
<td>Spanish 3 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Spanish 4 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Spanish 5 (4 units) plus 4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Spanish Literature</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>8 units maximum for both tests</td>
<td></td>
</tr>
<tr>
<td>Mathematics (AB Test: Calculus)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4 units</td>
<td>May be applied toward Mathematics 31A</td>
</tr>
<tr>
<td>Mathematics (BC Test: Calculus)</td>
<td>3</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4 excess units plus 4 units</td>
<td>4 units may be applied toward Mathematics 31A</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8 units</td>
<td>Mathematics 31A plus 4 units that may be applied toward Mathematics 31B</td>
</tr>
<tr>
<td>Music Theory</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td>8 units maximum for all tests</td>
<td></td>
</tr>
<tr>
<td>Physics 1</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics 2</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (B Test)</td>
<td>3, 4, or 5</td>
<td>8 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Mechanics)</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>4 units (may be applied toward Physics 1A)</td>
<td>No application</td>
</tr>
<tr>
<td>Physics (C Test: Electricity and Magnetism)</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td>Psychology</td>
<td>3</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
<tr>
<td></td>
<td>4 or 5</td>
<td>Psychology 10 (4 excess units)</td>
<td>No application</td>
</tr>
<tr>
<td>Statistics</td>
<td>3, 4, or 5</td>
<td>4 excess units</td>
<td>No application</td>
</tr>
</tbody>
</table>
ment, but to be competitive the applicant must take a C++ course equivalent to UCLA Computer Science 31. Applicants to Chemical Engineering may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but lack of a MATLAB course equivalent to UCLA Mechanical and Aerospace Engineering M20 or Civil and Environmental Engineering M20 will delay time to graduation. Applicants to all other engineering majors may take any C++, C, Java, or MATLAB course to satisfy the admission requirement, but the MATLAB course equivalent to Mechanical and Aerospace Engineering M20 or Civil and Environmental Engineering M20 is preferred.

5. One year of biology for applicants to the Bioengineering major is recommended.

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

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

Lower-Division Courses in Other Departments

Chemistry and Biochemistry 20A. Chemical Structure (4 units)
Chemistry and Biochemistry 20B. Chemical Energetics and Change (4 units)
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 University requirements, school requirements, and department requirements for the Bachelor of Science degree.

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

To receive a bachelor’s degree in any UCLA Samueli major, students must complete a minimum of 180 units. The maximum allowed is 213 units.

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

Scholarship Requirement

In addition to the requirement of at least a C (2.0) grade-point average in all courses taken at any UC campus, students must achieve at least a 2.0 grade-point average in all upper-division 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 at UCLA Samueli 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 UC 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 a grade of C or better in each (a C–grade is not acceptable).

Writing I

The Writing I requirement must be satisfied by completing English Composition 3, 3D, 3DS, 3E, or 3SL with a grade of C or better (a C– or Passed grade is not acceptable) by the end of the second year of enrollment. The Writing I requirement may also be satisfied by (1) scoring 4 or 5 on one of the College Board Advanced Placement Examinations in English, (2) a combination of a score of 720 or better on the SAT Reasoning Test, Writing section (last administered in January 2016) and superior performance on the English Composition 3 Proficiency Examination, (3) completing a course equivalent to English Composition 3 with a grade of C or better (a C– or Passed grade is not acceptable) taken at another institution, or (4) scoring 5, 6, or 7 on an International Baccalaureate Higher Level Examination. Students whose native language is not English may need to take English Composition 1A, 1B, and 2I before enrolling in a Writing I course. All courses in the sequence must be passed with a grade of C or better (a C– or Passed grade is not acceptable).

Engineering Writing

The engineering writing requirement is satisfied by selecting one approved engineering writing (EW) course from the school writing course list or by selecting one approved Writing II (W) course. The course must be completed with a grade of C or better (a C– or Passed grade is not acceptable). Writing courses are published in the Schedule of Classes at https://sa.ucla.edu/ro/public/soc.
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 school 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 181EW, 182EW, 183EW; or 185EW with a grade of C or better (a C– or 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 reveals to students the ways that research scholars in the arts, humanities, social sciences, and natural sciences create and evaluate new knowledge, introduces students to the important ideas and themes of human cultures, fosters appreciation for the many perspectives and the diverse voices that may be heard in a democratic society, and 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 chapter of the UCLA General Catalog or consult with 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

Courses in this area provide perspectives and intellectual skills necessary to comprehend and think critically about our situation in the world as human beings. In particular, courses provide the basic means to appreciate and evaluate the ongoing efforts of humans to explain, translate, and transform their diverse experiences of the world through such media as language, literature, philosophical systems, images, sounds, and performances. These 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

Courses in this area 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 is satisfied for Civil Engineering majors by the natural science requirement.

Courses in this area ensure that students gain a fundamental understanding of how scientists formulate and answer questions about the operation of both the physical and biological world. 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 with an academic counselor or see https://www.registrar.ucla.edu/Academics/GE-Requirement.

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 UCLA Samuel GE requirements. The school does not accept partial IGETC.
Department Requirements

UCLA Samuei departments generally set two types of requirements that must be satisfied for award of a degree: preparation for the major (lower-division courses) and 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 chapter 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 chapter 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 UCLA or other academic action.

Undergraduate students in the school are expected to enroll in at least 12 units each term. Students enrolling in fewer than 12 units must obtain approval by petition to the dean before enrolling in classes. 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 UCLA Samuei 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 credit table.

College Level Examination Program

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

Community College/Lower Division Transfer Limitation

Effective for students admitted fall 2017 and later, after completing 105 lower-division quarter units toward the degree in all institutions attended, students are allowed no further unit credit for courses completed at a community college or for lower-division courses completed at any institution outside of the University of California. The University of California does not grant transfer credit for community college or lower-division courses beyond 105 quarter units, but students may still receive subject credit for this coursework to satisfy lower-division requirements. Units earned through Advanced Placement (AP), International Baccalaureate (IB), and/or A-Level examinations are not included in the limitation. Units earned at any UC campus (through extension, summer, cross-campus, UCEAP, Intercampus Visitor Program, and regular academic year enrollment) are not included in the limitation. To convert semester units into quarter units, multiply the semester units by 1.5; for example, 12 semester units x 1.5 = 18 quarter units. To convert quarter units into semester units, multiply the quarter units by .666; for example, 12 quarter units x .666 = 7.99 or 8 semester units.

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 or fewer units, 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

UCLA Samuei students in good academic standing may be permitted to have a minor or double major. The minor or second major must be outside the school (e.g., Electrical Engineering major and Economics major). UCLA Samuei students are not permitted to have a 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. Students interested in a minor or double major should meet with their counselor in 6426 Boelter Hall.

While the school considers minor or double major requests, specializations are not considered.

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. Freshman students are assigned a faculty adviser in their particular specialization.

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 degrees, and UC, UCLA, and school regulations and procedures. It is the student’s responsibility to periodically meet with the academic counselor, as well as with the faculty adviser, to discuss curriculum requirements, programs of study, and any other academic matters of concern.

Curricula Planning Procedure

Students normally follow the curricula in effect when they enter the school. California community college transfer students may also select the curriculum in the UCLA General Catalog in effect at the time they began their community college work in an engineering program, provided attendance has been continuous since that time.

Students admitted to UCLA in fall quarter 2012 and thereafter use the Degree Audit system, which can be accessed through MyUCLA at http://my.ucla.edu. Students should contact their academic counselor in 6426 Boelter Hall with any questions.

UCLA Samueli undergraduate students following a Catalog year prior to fall quarter 2012 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 UCLA 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 2018-19 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 that places them in the top five percent of the school (GPA of 3.885 or better) for summa cum laude, next five percent (GPA of 3.816 or better) for magna cum laude, and the next 10 percent (GPA of 3.698 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 applied to a specific UCLA Samueli degree requirement, engineering students must also have a 3.885 grade-point average for summa cum laude, a 3.816 for magna cum laude, and a 3.698 for cum laude. For all designations of honors, students must have a minimum 3.25 GPA in their major field upper-division courses. Upper-division courses that are not applied to a specific school BS degree requirement are excluded from these upper-division averages.
Graduate Programs

The Henry Samueli School of Engineering and Applied Science offers courses leading to the Master of Science and Doctor of Philosophy degrees, Master of Science in Engineering online degree, Master of Engineering degree, and 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 and computer 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 https://grad.ucla.edu.

Master of Science Degrees

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

Concurrent Degree Program

A concurrent degree program between UCLA Samueli 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.

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 more information, see https://www.msol.ucla.edu.

The individual degrees include:
- Engineering (online M.S.)
- Engineering—Aerospace (online M.S.)
- Engineering—Computer Networking (online M.S.)
- Engineering—Electrical (online M.S.)
- Engineering—Electronic Materials (online M.S.)
- Engineering—Integrated Circuits (online M.S.)
- Engineering—Manufacturing and Design (online M.S.)
- Engineering—Materials Science (online M.S.)
- Engineering—Mechanical (online M.S.)
- Engineering—Signal Processing and Communications (online M.S.)
- Engineering—Structural Materials (online M.S.)

Master of Engineering Degree

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

Engineer Degree

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

Ph.D. Degrees

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

Established Fields of Study for the Ph.D.

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

Bioengineering Department
- Biomedical instrumentation
- Biomedical signal and image processing
- Biosystems science and engineering
- Medical imaging informatics
- Molecular cellular tissue therapeutics
- Neuroengineering

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 structural/earthquake engineering)

Computer Science Department
- Artificial intelligence
- Computational systems biology
- Computer network systems
- Computer science theory
- Computer system architecture
- Data science computing
- Graphics and vision
- Software systems

Electrical and Computer Engineering Department
- Circuits and embedded systems
- Physical and wave electronics
- Signals and systems
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.

To submit a graduate application, see https://www.seasoasa.ucla.edu/graduate-admissions-2/. From there connect to the site of the preferred department or program and go to the online graduate application.

Graduate Record Examination

Educational Testing Service
P.O. Box 6000, Princeton, NJ 08541-6000
https://www.ets.org/gre/

Applicants to UCLA Samueli 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 Educational Testing Service.
Departments and Programs of the School

Bioengineering

5121 Engineering V
Box 951600
Los Angeles, CA 90095-1600
310-267-4985
bioeng@hssas.ucla.edu
https://www.bioeng.ucla.edu

Song Li, Ph.D., Chair
Dino Di Carlo, Ph.D., Graduate Vice Chair
Jacob Schmidt, Ph.D., Undergraduate Vice Chair

Professors

Denise Aberle, M.D.
Pei-Yu Chiou, Ph.D.
Mark S. Cohen, Ph.D., in Residence
Linda L. Demer, M.D., Ph.D.
Timothy J. Deming, Ph.D.
Dino Di Carlo, Ph.D.
Robin L. Garrell, Ph.D.
Warren S. Grundfest, M.D., FACS
Zhen Gu, Ph.D.
Dean Ho, Ph.D.
Tzung Hsiai, M.D., Ph.D., in Residence
Bahram Jalali, Ph.D.
Daniel T. Kamen, Ph.D.
H. Pirouz Kavehpoor, Ph.D.
Alireza Khademhosseini, Ph.D. (Levi James Knight, Jr. Professor of Engineering)
Chang-Jin (CJ) Kim, Ph.D., (Volgenau Endowed Professor of Engineering)
Debiso Li, Ph.D., in Residence
Song Li, Ph.D. (Chancellor’s Professor)
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.
Jacob Rosen, Ph.D.
Jacobs J. Schmidt, Ph.D.
Kalayan 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.

Professors Emeriti

Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor Emeritus of Aeronautics)
Edward R.B. McCabe, M.D., Ph.D. (Mattel Executive Endowed Professor Emeritus of Pediatrics)

Associate Professor

Andrea M. Kasko, Ph.D.

Assistant Professors

Aaron S. Meyer, Ph.D.
Stephanie K. Seidlits, Ph.D.

Adjunct Associate Professor

Bill J. Tawil, M.B.A., Ph.D.

Adjunct Assistant Professors

Chase Linsley, Ph.D.
Kayvan Niazi, Ph.D.

George N. Saddik, Ph.D.
Zachary Taylor, Ph.D.

AFFILIATED FACULTY

Professors

Peyman Benharash, M.D. (Cardiothoracic Surgery)
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. (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Yong Chen, Ph.D. (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Thomas Chou, Ph.D. (Biomathematics, Mathematics)
Samson A. Chow, Ph.D. (Molecular and Medical Pharmacology)
Joseph L. Demer, M.D., Ph.D. (Neurology, Ophthalmology)
Katrina M. Dipple, M.D., Ph.D. (Human Genetics, Pediatrics)
Joseph J. DiStefano III, Ph.D. (Computer Science, Medicine)
Bruce S. Dunn, Ph.D. (Materials Science and Engineering)
Jeffrey D. Eldredge, Ph.D. (Mechanical and Aerospace Engineering)
Alan Garfinkel, Ph.D. (Cardiology, Integrative Biology and Physiology)
Christopher C. Giza, Ph.D., in Residence (Neurosurgery, Surgery)
Thomas G. Graebner, Ph.D. (Molecular and Medical Pharmacology)
Robert P. Gunsalus, Ph.D. (Microbiology, Immunology, and Molecular Genetics)
Vijay Gupta, Ph.D. (Materials Science and Engineering, Mechanical and Aerospace Engineering)
Y. Jinho Ju, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koehler, M.D., in Residence (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Pediatrics)
Elliot M. Landaw, M.D., Ph.D. (Biomathematics)
Mun Loo, Ph.D. (Dentistry)
Karen M. Lyons, Ph.D. (Molecular, Cell, and Developmental Biology, Orthopaedic Surgery)
Dejan Markovic, Ph.D. (Electrical and Computer Engineering)
Thomas G. Mason, Ph.D. (Chemistry and Biochemistry, Physics and Astronomy)
Heather D. Maynard, Ph.D. (Chemistry and Biochemistry)
Harry McKelvey, Ph.D., in Residence (Orthopaedic Surgery)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Monbouquette, 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., M.D., Ph.D. (Dentistry)
Matteo Pellegrini, Ph.D. (Human Genetics, Molecular, Cell, and Developmental Biology)
Laurent Pilon, Ph.D. (Mechanical and Aerospace Engineering)

Zhiqin 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)
Chia B. Soo, M.D. (Plastic Surgery)
Igor Spigelman, Ph.D. (Dentistry)
Ricky Taira, Ph.D., in Residence (Radiological Sciences)
Albert Thomas, Ph.D., in Residence (Radiological Sciences)
Johann C. Tidball, Ph.D. (Integrative Biology and Physiology, Pathology and Laboratory Medicine)
Kang Ting, D.M.D., M.D.Sc. (Dentistry)
Hsian-Rong Tseng, Ph.D. (Molecular and Medical Pharmacology)
Jack Van Horn, Ph.D. (Neurology)
David Wang, Ph.D. (Dentistry)
Lily Wu, Ph.D., M.D. (Molecular and Medical Pharmacology, Urology)
Xinshu Grace Xiao, Ph.D. (Integrative Biology and Physiology)
Z. Hong Zhou, Ph.D. (Microbiology, Immunology, and Molecular Genetics)

Professors Emeriti

Tony F. Chan, Ph.D. (Mathematics)
V. Reggie Edgerton, Ph.D. (Integrative Biology and Physiology)

Associate Professors

Aydin Babakhani, Ph.D. (Electrical and Computer Engineering)
James W. Bisley, Ph.D. (Neurobiology, Psychology)
Louis S. Bouchard, Ph.D. (Chemistry and Biochemistry)
Robert N. Candler, Ph.D. (Electrical and Computer Engineering, Mechanical and Aerospace Engineering)
Benjamin M. Ellington, Ph.D. (Radiology)
Peng Hu, Ph.D. (Radiology)
Jean-Pierre Hubuschman, M.D., in Residence (Ophthalmology)
Daniel S. Levi, Ph.D. (Pediatrics)
Zili Liu, Ph.D. (Psychology)
Nader Pouratian, Ph.D. (Neurosurgery)
Amy C. Rowat, Ph.D. (Integrative Biology and Physiology)
Veronica J. Santos, Ph.D. (Mechanical and Aerospace Engineering)
Ladan Shams, Ph.D. (Psychology)
Michael R. van Dam, Ph.D. (Molecular and Medical Pharmacology)
Zhaoyang Fan, Ph.D. (Integrative Biology and Physiology)

Assistant Professors

Sam Emaninejad, Ph.D. (Electrical and Computer Engineering)
Zhaoyang Fan, Ph.D. (Medicine)
William Hsu, Ph.D. (Radiology)
Neema Jamshidi, Ph.D. (Radiological Sciences)
Sotiris C. Masmanidis, Ph.D. (Neurobiology)
Dan Ruan, Ph.D. (Radiation Oncology)
Behzad Sharif, Ph.D. (Medicine)
Kyun Hyun Sung, Ph.D. (Radiology)
Holden H. Wu, Ph.D. (Radiology)
Scope and Objectives

The faculty members in the Department of Bioengineering have created state-of-the-art facilities for cutting-edge research and developed an innovative curriculum for the education of the next generation of bioengineers. The bioengineering program offers 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 Educational 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

Learning Outcomes

The Bioengineering major has the following learning outcomes:

- Application of advanced knowledge of mathematics, science, and engineering principles to address problems at the interface of biology and engineering
- Design of a system, component, or process to meet desired needs
- Function as a productive member of a multidisciplinary team
- Effective oral and written communication
- Identification, formulation, and solution of engineering problems

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 GE life sciences requirement) and 3, or 7A (satisfies GE life sciences requirement) and 7C; 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, 167L, 176, 180, Electrical and Computer Engineering 100, Engineering 183EW or 185EW; 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, M153, 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, 111, 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, M153, C172, 199 (8 units maximum), Electrical and Computer Engineering 102, Mechanical and Aerospace Engineering C187L. The electrical and computer 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 UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Graduate Study
For information on graduate admission, see Graduate Programs on page 25.

The following introductory information is based on 2018-19 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. 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 plan, 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 plan, 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 only once, 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 only once, subject to the approval of the faculty examination committee. Students who fail the examination twice are subject to recommendation for termination.

Within three terms after passing the Ph.D. preliminary examination, students are strongly encouraged to take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into student preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

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

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

Fields of Study

Biomedical Instrumentation
The biomedical instrumentation (BMI) field is designed to train bioengineers interested in the applications and development of instrumentation used in medicine and biotechnology. Examples include the use of lasers in surgery and diagnostics, new microelectrical machines for surgery, sensors for detecting and monitoring of disease, microfluidic systems for cell-based diagnostics, new tool development for basic and applied life sciences research, and controlled drug delivery devices. The principles underlying each instrument and specific clinical or biological needs are emphasized. Graduates are targeted principally for employment in anca-
denia, 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), Bioengineering M153 (or Electrical and Computer Engineering M153 or Mechanical and Aerospace Engineering M183B), Electrical and Computer 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.

Biomedical Signal and Image Processing

The biomedical signal and image processing (BSIP) field 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.

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


Biomedical Science and Engineering

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 biomedical systems (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 biomedical systems 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.

Course Requirements

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 Biostatistics 220 or 296B.


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

Medical Imaging Informatics

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

Course Requirements


Group II: Field Specific Courses. M.S. comprehensive students must take three courses and Ph.D. students must take six courses from any of the following concentrations:

- Computer Understanding of Images: Computer Science M266A, M266B, Electrical and Computer Engineering 211A, Physics and Biology in Medicine 210, 214, M219, M230
- Computer Understanding of Text and Medical Information Retrieval: Computer Science 263A, Information Studies 228, 245, 246, 260, Linguistics 221, 222, Statistics M231
- Information Networks and Data Access in Medical Environment: Computer Science 240B, 244A, 246
- Probabilistic Modeling and Visualization of Medical Data: Biostatistics M323, M234, M235, M236, Computer Science 241B, 262A, M262C, Epidemiology 212, Information Studies 272, 277

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

Molecular Cellular Tissue Therapeutics

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

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

Course Requirements

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

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


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

Neuroengineering

The neuroengineering (NE) field is designed to enable students with a background in biological sciences to develop and execute projects that make use of state-of-the-art technology, including microelectromechanical systems (MEMS), signal processing, and photonics. Students with a background in engineering develop and execute projects that address problems that have a neuroscientific base, including locomotion and pattern generation, central control of movement, and the processing of sensory information. Trainees develop the capacity for the multidisciplinary teamwork, in intellectually and socially diverse settings, that is necessary for new scientific insights and dramatic technological progress in the twenty-first 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: Field Specific Courses. Bioengineering M260, M261A, M284, and one course from 165EW, Biostatistics M261, Microbiology, Immunology, and Molecular Genetics C134, or Neuroscience 207.

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

- Neuroscience: Bioengineering C206, M263, Neuroscience M201, M202, 205
Faculty Areas of Thesis Guidance
Professors
Denise ABERLE, M.D. (U. Kansas, 1979)
Medical imaging informatics: imaging-based clinical trials, medical data visualization
Pei-Yu CHOU, Ph.D. (UC Berkeley, 2005)
Optofluidics systems
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
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, supramolecular materials, organometallic catalysis, biomimetic materials, polypeptides
Dino Di Carlo, Ph.D. (UC Berkeley, 2006)
Microfluidics, biomedical microdevices, cellular diagnostics, cell analysis and engineering
Robin L. Garrell, Ph.D. (U. Michigan, 1984)
Biological moleculare 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
Zhen Gu, Ph.D. (UCLA, 2010)
Drug delivery, biomaterials, cell therapy, micro- and nano-biotechnology
Tzung HSIAI, M.D. (U. Chicago, 1993), Ph.D. (UCLA, 2001)
Cardiovascular mechnotransduction, 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
Daniel T. KAMEI, Ph.D. (MIT, 2001)
Molecular cell bioengineering, rational design of molecular therapeutics, systems-level analysis of cellular processes, drug delivery, diagnostics
H. Pirouz Kavehpour, Ph.D. (MIT, 2003)
Microscale fluid mechanics, transport phenomena in biological systems, physics of contact line phenomena, complex fluids, non-isothermal flows, micro- and nano-heat guides, microbiology
Alireza Khademhosseini, Ph.D. (MIT, 2005)
Biomaterials, tissue engineering, organ-on-a-chip, stem cell engineering, biofabrication, micro- and nano-technology, biomedical devices
Chang-Jin (CJ) Kim, Ph.D. (UC Berkeley, 1991)
Microelectromechanical systems (MEMS), micro/nano fabrication technologies, structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)
Debalso LI, Ph.D. (U. Virginia, 1992)
Development and clinical application of fast MR imaging techniques for the evaluation of the cardiovascular system
Song Li, Ph.D. (UC San Diego, 1997)
Stem cell engineering, tissue engineering and vascular remodeling, mechanobiology/mechano-transduction
Wentai Liu, Ph.D. (U. Michigan, 1983)
Neural engineering
Aman Mahajan, M.D. (U. Delhi, India, 1991), Ph.D. (UCLA, 2006)
Arhythymia, cardiac imaging, patent foramen ovale repair, transosophageal echocardiogram, transthoracic echocardiography, valvuloplasty
Aydogan Ozcan, Ph.D. (Stanford, 2000)
Phototronics- and bio-technology
Jacob Rosen, Ph.D. (Tel Aviv U., Israel, 1997)
Natural integration of a human arm/powered exoskeleton system
Jacob J. Schmidt, Ph.D. (U. Minnesota, 1999)
Bioengineering and biophysics at micro and nanoscales, membrane protein engineering, biological-inorganic hybrid devices
Kalyanam Shivkumar, M.D. (U. Madras, India, 1990), Ph.D. (UCLA, 1999)
Mechanisms of cardiac arrhythmias in humans, complex catheter ablation, medical technology for cardiovascular therapeutics
Rien Sun, Ph.D. (Yale, 1993)
Integration of biology and nanotechnology to define underlying mechanism and develop new diagnostic and therapeutic approaches, with murine gammaherpesvirus 68 (MHV-68) as an in vivo model
Yi Tang, Ph.D. (Caltech, 2002)
Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel anti-biotics/antitumor products
Immune system development and cancer; regulation of gene expression in development and malignancy; linking RNA processing with mitochondrial homeostasis, metabolism and proliferation; nanoscale evaluation of malignant transformation
Molecular signaling (NF-KB and Wnt) tumor invasive growth and metastasis, adult mesenchymal stem cells, dental stem cells and regenerative medicine, inflammation and innate immunity
Gerald C.L. Wong, Ph.D. (UC Berkeley, 1994)
Cancer cell biology, viral latency, viral carcinogenesis, potential therapies, independent medical technology for cardiovascular and cardiology research
Gerald C.L. Wong, Ph.D. (UC Berkeley, 1994)
Cancer cell biology, viral latency, viral carcinogenesis, potential therapies, independent medical technology for cardiovascular and cardiology research
Yang Yang, Ph.D. (U. Massachusetts Lowell, 1992)
Conjugated polymers and applications in optoelectronic devices such as light-emitting diodes, photodiodes, and field-effect transistors
Professors Emeriti
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Molecular fluidic phenomena, microelectromechanical systems (MEMS), biomolecular sensor arrays, control of cellular complex systems, rapid search of complex catheter ablation, medical technology for cardiovascular therapeutics
Stem cell identification, regenerative medicine, systems biology
Associate Professor
Andrea M. Kasko, Ph.D. (U. Akron, 2004)
Polymer synthesis, biomaterials, tissue engineering, cell-material interactions
Assistant Professors
Aaron S. Meyer, Ph.D. (MIT, 2014)
Molecular cell bioengineering, systems-level cellular signaling analysis, model-driven design and analysis, cancer and innate immune signaling
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 Associate Professor
Skin tissue engineering, bone tissue engineering, vascular tissue engineering, wound healing
Adjunct Assistant Professors
Chase Linsley, Ph.D. (UCLA, 2015)
Biomaterials, tissue engineering, drug delivery, additive manufacturing
Kayvan Niazi, Ph.D. (UCLA, 2000)
Molecular and cellular bioengineering, immunotherapeutics
George N. Saddik, Ph.D. (UC Santa Barbara, 2011)
Ultrasonic transducer and system engineering, bulk acoustic wave resonators and filters, RF and microwave circuits and system design
Zachary Taylor, Ph.D. (UC Santa Barbara, 2010)
THz imaging, laser-generated shockwaves
Affiliated Faculty
For areas of thesis guidance, see http://www.bioeng.ucla.edu/about-your-faculty-adviser.
Lower-Division Courses
10. Introduction to Bioengineering. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Preparation: high school biology, chemistry, mathematics, physics. Introduction to scientific and technological bases for established and emerging subfields of bioengineering, including biosensors, bioinstrumentation, and biosignal processing, biomechanics, biomaterials, tissue engineering, biotechnology, biological imaging, biomedical optics and lasers, bioengineering and biomolecular machines. Letter grading. Mr. Deming (F)
19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current and intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.
99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower-division students under guidance of faculty mentor. Students must be in good academic standing and enrolled in minimum of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.
Upper-Division Courses
100. Bioengineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A, Physics 1A. Fundamental basis for analysis and design of biological and biomedical devices and systems. Classical and statistical thermodynamic analysis of biological systems. Material, energy, charge, and force balances. Introduction to network analysis. Letter grading. Mr. Kamei (F)
C101. Engineering Principles for Drug Delivery. (4) 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 re-
coupled biomolecules for wide range of applications. Highly recommended: one organic chem-

C107. Polymer Chemistry for Bioengineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course C104 or C105. Fundamental concepts of polymer synthesis, in-

C108. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; out-

C104. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aero-

C147. Applied Tissue Engineering: Clinical and Indus-

cial and Aerospace Engineering CM141.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Major broad overview of basic biological activities and organization of human body in system (organ), tissue, cellular, and molecular basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visit to offices and facilities. Concurrently sched-

C145. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Course 100, 120, Life Sciences 2, 3, Physics 1C, and 124B. Emphasis on silicon-based microfabricated and nanofabricated sensors. Novel materials, biocompat-

C110. Nanopore Sensing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, Physics 1C. Simultaneous measurement of ionic currents through nanopore force-extension, DNA packing and transcriptional regulation, lipid bilayer membranes, mechanisms of cytoskeleton, molecular motors, biological electric-

C105. Engineering of Bioconjugates. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chem-

C111. Biological Networks. (4) (Same as Chemical Engineering CM141.) Lecture, four hours; discussion, two hours; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 2, 3, Mathematics 33B, Physics 1C. Functional level of biological function. Illustration of these ideas using examples from bioengineering and biomedical engineering.

C106. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, six hours. Requisites: Chemistry 20A, 20B, 20L, Life Sciences 2, 3, Mathematics 33B, Physics 1C. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physi-

C139B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course C139A is not requisite to C139B. Overview of chemical and physical founda-

C139A. Biomolecular Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomaterials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of biomolecules, with emphasis on nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into functional forms via self-assembly and how these structures im-

CM130. Human Physiological Systems for Bioen-

CM102. Human Physiological Systems for Bioen-

CM103. Human Physiological Systems for Bioen-

CM141. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course CM102, Chemistry 20A, 20B, 20L, Life Sciences 2, 3, Mathematics 33B, Physics 1C. Functional level of biological function. Illustration of these ideas using examples from bioengineering and biomedical engineering. Understanding of different basic types of biomolecules, with emphasis on nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into functional forms via self-assembly and how these structures im-

Mr. Wong (Sp)


Lecture; three hours; laboratory; four hours; outside study, four hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 2A, 4C, 48L. Introduction to general manufacturing methods, mechanisms, constraints, and microfabrication and nanofabrication. Focus on concepts and experiments of various microfabrication and nanofabrication techniques that have been broadly applied in industry and academia, including various photolithography technologies, physical and chemical methods, and thermal and chemical etching methods. Hands-on experience for fabricating microstructures and nanostructures in modern cleanroom environment. Letter grading. Mr. Chiang (Sp)

C155. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Enforced requisite: course 110. Introduction to Navier/Stokes equations, assumptions, and simplifications. Analytical framework for calculating simple flows and numerical methods to solve and gain intuition for 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: field-flow fractionation, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics fundamentals, 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 that addresses ethical problems about life, 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 in practice. Engineering ethics addresses ethical problems about producing devices from molecules to bridges, such as when do concerns about risk outweigh concerns about cost? When are weapons too dangerous to design? At what point does benefit of committing to building devices from molecules to bridges outweigh the harms? Working in teams, students develop innovative solutions to address current problems in medicine and biology. Students conduct direct experiments and computational modeling, give oral presentations, write reports, and participate in bioengineering design competition. Letter grading. Mr. Wu (Sp)

177A. Bioengineering Capstone Design I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 177A. Lecture, seminars, and discussions on aspects of biomedical device and therapeutic design, including topics such as need finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to address current problems in medicine and biology. Students conduct direct experiments and computational modeling, give oral presentations, write reports, and participate in bioengineering design competition. Letter grading. Mr. Di Carlo (W)

177B. Bioengineering Capstone Design II. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 177A. Lecture, seminars, and discussions on aspects of biomedical device and therapeutic design, including topics such as need finding, intellectual property, entrepreneurship, regulation, and project management. Working in teams, students develop innovative solutions to address current problems in medicine and biology. Students conduct direct experiments and computational modeling, give oral presentations, write reports, and participate in bioengineering design competition. Letter grading. Ms. Kaska (Sp)

180L. System Integration in Biology, Engineering, and Medicine I. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Enforced requisites: courses 100, 110, 120, Life Sciences 3, Psychology 20L. Corequisite: course 110. Introduction of two-part series. Molecular basis of normal physiology and pathophysiology, and engineering design principles of cardiovascular and pulmonary systems. Fundamentals of engineering principles for selected medical devices. Letter grading. Mr. Dunn, Mr. Wu (W)

M182. Systems Biomodeling and Simulation Basics. (4) (Same as Computer Science M182.) Lecture, three hours; discussion, one hour; laboratory, two hours. Outside study, seven hours. Corequisites: Mathematics 20A, 20B, or Life Sciences 30A. Precalculus. Concurrently scheduled with course C283. Letter grading. Ms. Kaska (Sp)

C183. Targeted Drug Delivery and Controlled Drug Release. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Corequisite: course 177A. Lecture, seminars, and discussions on aspects of drug 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 engineering principles (dissolution, transport, kinetics) to problems in drug formulation and delivery to establish rational 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 compounds used in delivery and release. Concurrently scheduled with course C253. Letter grading. Ms. Kaska (Sp)

M184. Introduction to Computational and Systems Biology. (2) (Same as Computational and Systems Biology M184 and Computer Science M184.) Lecture, two hours; outside study, four hours. Enforced requisites: one course from Civil Engineering M20, Computer Science M51, Mechanical and Aerospace Engineering M20, or Program in Computing 10A, and Mathematics 3B or 31B. Survey course designed to introduce students to computational and systems modeling and computation in biology and medicine, providing motivation, flavor, and culture of contemporary problems in biocompatibility. Concurrently scheduled with course C279. Letter grading. Ms. Kaska (Sp)

C171. Laser-Tissue Interaction II: Biologic Spectroscopy. (4) Lecture, four hours; outside study, eight hours. Requisite: course C170. Designed for physical sciences and life sciences majors. Introduction to optical spectroscopy principles, design of spectroscopic measurement devices, optical properties of tissues, and fluorescence spectroscopy biology. Concurrently scheduled with course C271. Letter grading. Mr. Grundfest (W)

C172. Design of Minimally Invasive Surgical Tools. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 30B, Life Sciences 2, 3, 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, biopsy devices, laparoscopic tools, cardiovascular and interventional radiology devices, orthopedic instrumentation, and interventional radiology devices. Examination of complex process of tool design, fabrication, testing, and validation. Preparation of drawings and consideration of development of new and novel devices. Concurrently scheduled with course C272. Letter grading. Mr. Grundfest (W)

176. Principles of Biocompatibility. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 100, Mathematics 33B, Physics 1C. Biocompatibility at systemic, tissue, cellular, and molecular levels. Biomechanical compatibility, stress/strain constitutive equations, cellular and molecular response to mechanical signals. Modeling of cellular compatibility and immune response. Letter grading. Mr. Wu (Sp)

C177A. Introduction to Biomaterials. (4) (Same as Materials Science M180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged tissues. Focus on how material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM278. Letter grading. Mr. Dunn, Mr. Wu (W)

C178. Introduction to Biotechnology. (4) Lecture, two hours; outside study, nine hours. Requisite: course C178. In-depth exploration of host cellular response to biomaterials: vascular response, inflammation, infection, extracellular matrix, cell adhesion, and role of mechanical forces. Concurrently scheduled with course C279. Letter grading. Mr. Dunn, Mr. Wu (W)

Lecture, three hours; laboratory, four hours; outside study, four hours. Enforced requisites: Chemistry 20A, 20B, 20L. Laboratory experiments in fluorescence microscopy, bioconjugation, soft lithography, and cell culture culminate in design of engineered surface for cell growth. Introduction to techniques and tools for developing physical or chemical properties. Case studies connect laboratory techniques to current biomedical engineering research and reinforce experimental design skills. Ms. Kaska (Sp)

C170. Energy-Tissue Interactions. (4) Lecture, three hours; outside study, nine hours. Enforced requisites: Life Sciences 2, Physics 1C. Introduction to and diagnostic use of energy delivery devices in medical applications with emphasis on understanding fundamental mechanisms underlying various types of energy-tissue interactions. Concurrently scheduled with course C270. Letter grading. Mr. Dunn, Mr. Wu (F)

C170L. Introduction to Techniques in Studying Laser-Tissue Interaction. (2) Laboratory, four hours; outside study, two hours. Corequisite: course C170. Introduction to simulation and experimental techniques used in studying laser-tissue interactions. Topics include computer simulations of light propagation, tissue, thermal absorption, and electro-optic properties of tissue/tissue phantom, making tissue phantoms, determination of optical properties of different tissues, and techniques of temperature distribution measurement. Concurrently scheduled with course C270L. Letter grading. (Not offered 2018-19)
C185. Introduction to Tissue Engineering. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: course CM102 or CM202, C204, C205, 20L. Tutorial, to be arranged. Limited to graduate students. Introduction to design and fabrication of three-dimensional scaffolds, and molecular signals. Concurrently scheduled with course C285. Letter grading.

Ms. Kasko (W)

CM189. Computational Systems Biology: Modeling and Biological Systems. (5) (Same as Computational and Systems Biology M186, Computer Science CM186, and Ecology and Evolutionary Biology M178.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multicompartamental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways), and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286. Letter grading. Mr. DiStefano (F)

CM187. Research Communication in Computational and Systems Biology. (5) (Same as Computational and Systems Biology M187 and Computer Science CM187.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Closely directed research course in which students design and write a research proposal on an 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. 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 CM287. Mr. Gentile (W)

188. Special Courses in Bioengineering. (4) Seminar, three hours. Limited to bioengineering undergraduate students who are part of research group. Study and analysis of current topics in bioengineering. Discussion of current research literature in research specialty of faculty member teaching course. Student presentation of projects in research specialty. May be repeated for credit with topic or instructor change. Letter grading. (W)

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

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


Mr. Kamei (F)

CM202. Human Physiological Systems for Bioengineering I. (4) Same as Physiology and Biophysics CM204.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiology 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 aspects of included. Practical demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM102. Letter grading.

Ms. Grundfest (W)

CM203. Human Physiological Systems for Bioengineering II. (4) (Same as Physiological Science CM203.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open for credit to Physiological Science majors. Molecular-level understanding of human anatomy and physiology in selected organ systems (digestive, skin, musculoskeletal, endocrine, nervous, respiratory, integumentary, etc.) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspects of included systems of use. Functional demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course CM103. Letter grading.

Mr. Grundfest (W)

C204. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L, Life Sciences 2, 3. To understand biophysical and chemical principles in biological systems, and design synthetic replacements, it is imperative to understand their physical chemistry. Investigations of polymer structure and conformation, bulk and solution properties of proteins, and functional aspects of complex multimeric proteins. Concurrently scheduled with course CM104. Letter grading.

Mr. Wong (F)

C205. Engineering of Bioconjugates. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface if gene chip, or one protein may be coupled to one polymer to enhance its stability in serum. Wide variety of bioconjugates are used in delivery of pharmaceuticals, in sensors, in medical diagnostics, and in tissue engineering. Basic concepts of chemical ligation, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as noncovalent linkers. Presentation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C105. Letter grading. Mr. DeLisi (F)

C206. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 2, 3, Mathematics 33B, Physics 1C. Coverage includes physical principles associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrosatistics in electric dielectrics and its application to electromechanical address potential and signal propagation in nerves. Topics include Nerst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, GHK equations, energy barriers in ion channels, cable equation, action potentials, Hodgkin/Huxley equations, capacitance properties, geometry and conduction, dendritic integration. Concurrently scheduled with course C106. Letter grading.

Mr. Schmidt (F)

C207. Polymer Chemistry for Bioengineers. (4) 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. Focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymerization. Presentation of models of use. Different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theoretical and practical issues demonstrated through examples. Concurrently scheduled with course C107. Letter grading.

Mr. Deming (W)

M214A. Digital Speech Processing. (4) (Same as Electrical and Computer Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: Electrical and Computer Engineering 113. Theory and applications of different speech processing of digital signals with emphasis on processing models of human speech production and perception mechanisms, speech analysis/synthesis. Techniques include linear prediction, filter-bank models, and homomorphic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Ms. Alwan (W)

M215. Biochemical Reaction Engineering. (4) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Chemical Engineering 101C. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and chemical engineering for study of chemical reactions, needed for design and economic analysis of biological reactors. Letter grading. Mr. Liao (Sp)

M217. Biomedical Imaging. (4) (Same as Electrical and Computer Engineering M217.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: Electrical and Computer Engineering 114 or 211A. Optical imaging modalities in biomedicine. Other nonoptical imaging modalities discussed briefly for comparison purposes. Letter grading.

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Same as Physics and Biology Medicine M219.) Lecture, three hours; discussion, one hour; outside study, eight hours. Introduction to techniques in rapid imaging, quantitative imaging, and spectroscopy. Letter grading.

220. Introduction to Medical Informatics. (2) Lecture, two hours; outside study, four hours. Designed for graduate students. Introduction to research topics and issues in medical informatics for students new to field. Definition of the research 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 retrieval, and information retrieval and visualization, health services research, telemedicine. Emphasis on current research endeavors and applications. S/U grading. Letter grading. Mr. Kangarloo (F)

221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Designed for graduate students. Introduction to anatomy and physiology, with particular emphasis on understanding and visualization of anatomy and physiology

Bioengineering / 35
through medical images. Topics relevant to acquisition, representation, and computer-aided detection of medical images are covered with a focus on the impact of these developments on medical diagnostics and treatment. This course is designed for graduate students.

**M224. Physics and Informatics of Medical Imaging.** (4) Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to principles of medical imaging and imaging informatics for non-physicists. Overview of core imaging modalities: X-ray, computed tomography (CT), magnetic resonance (MR). Topics include signal generation, localization, and quantization. Image representation and analysis techniques such as Markov random fields, spatial statistics, denoising, image representations, and clinical imaging workstations. Provides basic understanding of issues related to basic medical imaging data acquisition and analysis. Current research efforts with focus on clinical applications and new types of information made available through these modalities. Letter grading. Mr. Meng (F,WS,Sp)

**M224B. Advances in Imaging Informatics.** (4) Lecture, four hours; discussion, eight hours. Overview of informatics-based applications of medical imaging with a focus on various advances in field, such as content-based image retrieval, computer-aided detection/diagnosis, and image informatics. Introduction to core concepts in information retrieval (IR), review of seminal papers on evaluating IR systems and their use in medicine (e.g., teaching files, case-based retrieval, search), and specific techniques such as image feature extraction and processing, feature representation, indexing and querying, and classification (machine/deep learning). Survey of clinical applications of image informatics and emerging challenges. Letter grading. Mr. Morikawa (W)

**M225. Bioseparations and Bioprocess Engineering.** (4) (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 cells, enzymes, food additives, or pharmaceuticals that are products of biological reactors. Letter grading. Mr. Monbourquette (W)

**M226. Medical Knowledge Representation.** (4) (Same as Information Studies M254.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Issues related to medical knowledge representation and its application in healthcare processes. Topics include current methods to representing knowledge (conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based representations, 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 clinical informatics and design. Common medical ontologies, coding schemes, and standardized indices/terminologies (SNOMED, UMLS). Letter grading. Mr. Taip (Sp)

**M227. Medical Information Infrastructures and Internet Technologies.** (4) (Same as Information Studies M254.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to networking, communications, and information management of medical data. Exposure to basic concepts related to networking at several levels: low-level (TCP/IP, services), medium-level (network topologies), and high-level (distributed computing). Web-based services (implementations, common used medical communication protocols). Study of DICOM and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless health systems, peer-to-peer topology, grid/cloud computing. Introduction to security and encryption in networked environments. Letter grading. Mr. Bui (F)

**M228. Medical Decision Making.** (4) (Same as Information Studies M254.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Overview of issues related to medical decision making. Introduction to concept of evidence-based medicine and decision processes related to process of care and outcomes. Basic probability and statistics to understand research results and evaluations, and algorithmic methods for decision-making processes (Bayes theorem, decision trees). Study design, hypothesis testing, statistical decompilation, and concentration. Focus on technical advances in medical decision support systems and expert systems, with review of classic and current research. Introduction to common statistical summaries and decision-making software packages to familiarize students with current tools. Letter grading. Mr. Kangaroo (W)

**M229. Advanced Topics in Magnetic Resonance Imaging.** (4) (Same as Physics and Biology in Medicine M219.) Lecture, four hours. Requisite: course M219. Designed for students interested in pursuing research related to development or translation of new magnetic resonance imaging (MRI) technique. Basic tools and understanding of recent MRI developments that have had high impact on field, involve novel pulse sequence design or image reconstructions, and enable imaging of anatomy or function in way that was not possible in prior work with any modality. Topics include in-depth sequence simulation, RF pulse design, rapid image acquisition, parallel imaging, compressed sensing, image reconstruction, and processing of medical images using artificial intelligence. Letter grading. Mr. Monbourquette (W)

**C231. Nanopore Sensing.** (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 100, 120, Life Sciences 2, 3, Physics 1A, 1B, 1C. Analysis of sensors based on membrane channels. Nanopore sensors, detection through artificial or protein nanopores. Physics of pore conductance. Applications to single molecule detection and DNA sequencing. Review of current literature and technological applications. History and instrumentation of resistive pulse sensing, theory and applications. Single molecule detection of oligonucleotides, nanopore fabrication, ionic conductance through pores and GHK equation, patch clamp and single channel measurements and instrumentation, system of resistors, protein engineering, DNA sequencing, membrane engineering, and future directions of field. Concurrently scheduled with course C131. Letter grading. Mr. Schmitt (F)

**M233A. Bioseparations and Bioprocess Engineering.** (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Study design, hypothesis testing, statistical decompilation, and concentration. Focus on technical advances in medical decision support systems and expert systems, with review of classic and current research. Introduction to common statistical summaries and decision-making software packages to familiarize students with current tools. Letter grading. Mr. Liu, Mr. Shikivkumar (W)

**M233B. Medtech Innovation I: Entrepreneurial Opportunities.** (4) Lecture, three hours; outside study, nine hours. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Development of medtech solutions for unmet clinical needs previously identified in course M233A. Steps necessary to commercialize viable medtech solutions. Exploration of concept selection, business plan development, intellectual property filing, financing strategies, and device prototyping. Letter grading. Mr. Liu, Mr. Shikivkumar, Mr. Wu (Sp)

**C239A. Biomolecular Materials Science I.** (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, entropically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polymers and solutions for nanotechnology, and cellular recognition. Illustration of these ideas using examples from bioengineering and biomaterials science. Students should be able to make decisions about ideas that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139A. Letter grading. Mr. Wong (W)

**C239B. Biomolecular Materials Science II.** (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course C239A is not requisite to C239B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different types of interactions that exist between biomolecules, such as van der Waals interactions, entropically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polymers and solutions for nanotechnology, and cellular recognition. Illustration of these ideas using examples from bioengineering and biomaterials science. Case study on current topics, including drug delivery, gene therapy, cancer therapeutics, emerging pathogens, and relation of self-assembly to medical devices. Students should be able to make decisions about ideas that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139B. Letter grading. Mr. Wong (Sp)

**CM240. Introduction to Biomechanics.** (4) (Same as Medical and Aerospace Engineering ME240.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aerospace Engineering 101, 102, and 156A or 166A. Introduction to mechanical functions of human body;
M284. Functional Neuroimaging: Techniques and Applications. (3) (Same as Neuroscience M285, Physics and Biology in Medicine M285, Psychiatry M285, and Psychology M278J.) Lecture, three hours. In-depth examination of activation imaging, including MRI and PET/CT. Methods, data collection and analysis, experimental design, and results obtained thus far in human systems. Strong focus on understanding technologies, how to design activation imaging paradigms, and how to interpret results. Laboratory visits and design and implementation of functional MRI experiment. S/U or letter grading.

C285. Introduction to Tissue Engineering. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Dynamic biofilm modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multiparametric, predictive, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life science problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory. Concurrently scheduled with course CM186. Letter grading.

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Computer Science CM286.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Dynamic biofilm modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multiparametric, predictive, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life science problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory. Concurrently scheduled with course CM186. Letter grading.

CM287. Research Communication in Computational and Systems Biology. (4) (Same as Computer Science CM287.) Lecture, four hours; outside study, eight hours. Dynamics of biofilm modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multiparametric, predictive, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life science problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematics models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory. Concurrently scheduled with course CM1102, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course C185. Letter grading.

Mr. DiStefano (W)

CM295. Advanced Topics in Bioengineering. (4) (Same as Biomedical Engineering CM295B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biostatistics 220. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model training, theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading.

Mr. DiStefano (W)


Mr. DiStefano (Sp)

M296D. Introduction to Computational Cardiology. (4) (Same as Computer Science M296D.) Lecture, 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.

Mr. Kamei (F)

296. Special Studies in Bioengineering. (2) Seminar, four hours; outside study, four hours. Study of selected topics in bioengineering taught by resident and visiting faculty members. May be repeated for credit. Letter grading.

Mr. Kamei (F)

596. Directed Individual or Tutorial Study. (2 to 12) Tutorial, to be arranged. Limited to graduate bioengineering students. Petition forms to request enrollment may be obtained from program office. Supervised investigation of advanced technical problems. S/U grading.

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

597B. Preparation for PhD Preliminary Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

598. Research for and Preparation of MS Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate bioengineering students. Enables students who have been advanced to candidacy to proceed with search for research results. Major emphasis on effectice research reporting, both oral and written. Concurrently scheduled with course CM185. Letter grading.

Mr. DiStefano (Sp)

598A-598Z. Seminars: Research Topics in Bioengineering. (2 each) Seminar, two hours; outside study, four hours. Limited to bioengineering graduate students. Advanced study and analysis of current topics in bioengineering. Discussion of current research 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.

598A. Biomaterials Seminar. 598B. Bionics Seminar. 598C. Biomedical Engineering Seminar. 598D. Biophysics Seminar. 598E. Biomedical Imaging Seminar. 598F. Bioinstrumentation Seminar. 598G. Biomechanics Seminar. 598H. Biomedical Engineering Seminar. 598I. Biochemistry Seminar. 598J. Biophysical Seminar. 598K. Biophysics Seminar. 598L. Biomedical Engineering Seminar. 598M. Biomedical Engineering Seminar. 598N. Biomedical Engineering Seminar. 598O. Biomedical Engineering Seminar. 598P. Biomedical Engineering Seminar. 598Q. Biomedical Engineering Seminar. 598R. Biomedical Engineering Seminar. 598S. Biomedical Engineering Seminar. 598T. Biomedical Engineering Seminar. 598U. Biomedical Engineering Seminar. 598V. Biomedical Engineering Seminar. 598W. Biomedical Engineering Seminar. 598X. Biomedical Engineering Seminar. 598Y. Biomedical Engineering Seminar. 598Z. Biomedical Engineering Seminar.

599. Research for and Preparation of PhD Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Enables students who have been advanced to candidacy to proceed with search for research results. May be repeated for credit. S/U grading.

Mr. Kamei (F)
Chemical and Biomolecular Engineering

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Panagiotis D. Christofides, Ph.D., Chair
Philippe Sautet, Ph.D., Vice Chair

Professors
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)
Panagiotis D. Christofides, Ph.D. (William D. Van Vorst Professor of Chemical Engineering Education)
Yoram Cohen, Ph.D.
James F. Davis, Ph.D., Vice Provost
Vijay K. Dhir, Ph.D.
Alireza Khademhosseini, Ph.D.
Yunfeng Lu, Ph.D.
Vasilios I. Manoussiotakis, Ph.D.
Harold G. Monbouquette, Ph.D.
Stanley J. Osher, Ph.D.
Philippe Sautet, Ph.D.
Yi Tang, Ph.D., Chancellor’s Professor

Professors Emeriti
Robert F. Hicks, Ph.D.
Kendall N. Houk, Ph.D. (Saul Winstein Professor Emeritus of Organic Chemistry)
Louis J. Ignarro, Ph.D. (Nobel laureate, Jerome J. Belzer Professor Emeritus of Medical Research)
Eldon L. Knuth, Ph.D.
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor Emeritus of Chemical Engineering)
Ken Nobe, Ph.D.
Selim M. Senkan, Ph.D.
Vincent L. Vilker, Ph.D.
A.R. Frank Wazzan, Ph.D., Dean Emeritus

Assistant Professors
Nasim Annabi, Ph.D.
Yvonne Y. Chen, Ph.D.
Carlos G. Morales-Guiol, Ph.D.
Junyoung O. Park, Ph.D.
Dante A. Simonetti, Ph.D.
Samanvaya Srivastava, 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 nanoengineering. 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 Program Educational Objectives

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

The mission of the undergraduate program is to educate future leaders in chemical and biomolecular engineering who effectively combine their broad knowledge of physics, chemistry, biology, and mathematics with their engineering analysis and design skills for the creative solution of problems in chemical and biological technology and for the synthesis of innovative (bio)chemical processes and products. This goal is achieved by producing chemical and biomolecular engineering alumni who (1) draw readily on a rigorous education in mathematics, physics, chemistry, and biology in addition to the fundamentals of chemical engineering to creatively solve problems in chemical and biological technology, (2) incorporate social, ethical, environmental, and economical considerations, including the concept of sustainable development, into chemical and biomolecular engineering practice, (3) lead or participate successfully on multidisciplinary teams assembled to tackle complex 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 biological engineering. In all cases, balance is sought between engineering science and practice.

Learning Outcomes

The Chemical Engineering major has the following learning outcomes:

• Application of knowledge of mathematics, physics, chemistry, biology, and chemical and biological engineering, especially to integration of molecular- to micro-scale information into macro-scale analysis and design of chemical and biochemical processes and products
• Design of 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
Identification, formulation, and solution of complex chemical and biological engineering problems

Function as a productive member of a multidisciplinary team

Effective oral and written communication

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.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 104A, 104D, 107, 109, C115, C125, CM145; 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 Bioengineering C105, C183, Chemical Engineering C112, Chemistry and Biochemistry C105, 153A, or C159 (another chemical engineering elective may be substituted with approval of the faculty adviser).

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

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; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109, CM145; 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 Bioengineering C105, C183, Chemical Engineering C112, Chemistry and Biochemistry C105, 153A, or C159 (another chemical engineering elective may be substituted for one of these with approval of the faculty adviser).

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Biomolecular 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.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109; 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 UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

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; Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL.

The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104B, 106, 107, 109; 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 UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

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.
The Major

Required: Chemical Engineering 45, 100, 101A, 101B, 101C, 102A, 102B, 103, 104A, 104C, 104CL, 106, 107, 109, C116; 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 chemical engineering or from Materials Science and Engineering 104, 120, 121, 122, or 150.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Graduate Study

For information on graduate admission, see Graduate Programs on page 25.

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 2018-19 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. 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 MS degree are a thesis, nine courses (36 units), and a minimum 3.0 grade-point average in the graduate courses. Chemical Engineering 200, 210, and 220 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, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 150, 160, 161L, 198, Mechanical and Aerospace Engineering 102, 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 and Computer Engineering 123A, and Materials Science and Engineering 121. In addition, two departmental elective courses and two electrical and computer 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 CM214, C218, C219, 223, C240, Electrical and Computer 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 MS 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, CM245, 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 phenomena 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, biomolecular, and cellular engineering teaching and research. Facilities and equipment include bioreactors, fluorescence microcopy, real-time PCR thermocycler, UV-visible and fluorescence spectrophotometers, HPLC and LC-mass spectrometer, aerobic and anaerobic bioreactors from bench top to 100-liter pilot scale, protein purification facility, potentiostat/galvanostat and impedance analyzer for electroenzymology, membrane extruder and multiangle laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and phosphomager for biochemical assays involving radiolabeled compounds.

Microbial cells are genetically and metabolically engineered to produce compounds that are used as fuel, chemicals, drugs, and food additives. Novel gene-metabolic circuits are designed and constructed in microbial cells to perform complex and non-native cellular behavior. These designer cells are cultured in bioreactors, and intracellular states are monitored. Such investigations are coupled with genomic and proteomic efforts, and 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 antitumor activities. Biosensors are being micromachined for detecting neurotransmitters in vivo. New biosensing schemes also are being invented for the detection of endocrine disrupting chemicals in the environment and for the high-throughput screening of drug candidates. Naturally occurring protein nanocapsules are being redesigned at the genetic level for applications in drug delivery and materials synthesis. Finally, the enzymology of extremely thermophilic microbes is being explored for applications in specialty chemical synthesis.

Chemical Kinetics, Catalysis, and Reaction Engineering Laboratory

The Chemical Kinetics, Catalysis, and Reaction Engineering Laboratory is equipped with advanced research tools for experimental and computational studies of chemical kinetics, reaction engineering, and catalytic and adsorptive materials. Analytical instruments include a quadrupole mass spectrometer (QMS) system to sample reactive systems with electron impact and photoionization capabilities; several fully computerized gas chromatograph/mass spectrometer (GC/MS) systems for gas analysis; a computerized gas chromatograph/sulfur chemiluminescence detector (GC/SCD) system for gas analysis of sulfur-containing compounds; and fully computerized array channel micro-reactors and plug-flow reactors for catalyst discovery and optimization.

The laboratory also presents a strong expertise in computational catalysis and surface chemistry. It is equipped with state-of-the-art atomic-scale modeling software used to understand the properties of solids and the catalytic reactivity of surfaces, nanoparticles, and clusters. Codes include VASP, CP2K, and SIESTA. Applications domains are linked with chemistry and energy challenges and range from heterogeneous catalysis to photocatalysis, electrocatalysis, depollution, and electricity storage. Original simulation methods, developed by the researchers, are available for the modeling of electrocatalysis. A high-performance cluster is available for research and teaching. Campuswide computers are also available to laboratory researchers.

Electrochemical Engineering and Catalysis Laboratories

With instrumentation such as rotating ring-disk electrodes, electrochemical packed-bed flow reactors, gas chromatographs, potentiostats, and function generators, the Electrochemical Engineering and Catalysis Laboratories are used to study metal, alloy, and semiconductor corrosion processes, electro-deposition and electroless deposition of metals, alloys, and semiconductors for GMR and MEMS applications, electrochemical energy conversion (fuel cells) and storage (batteries), and bioelectrocatalytic 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, ultra-violet photoelectron spectroscopy, reflection high energy electron diffraction, spectroscopic ellipsometry, photoluminescence, and infrared spectroscopy; and a complete set of processing tools available for microelectronics and MEMS fabrication in the Nanoelectronic Research Facility. With the combined material characterization and electronic device fabrication, the reaction kinetics including composition and morphology, and the electrical property of these materials can be realized for applications in the next generation electronic devices and chemical or biological MEMS.

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

The atmospheric plasma laboratory is equipped with multiple plasma sources and state-of-the-art diagnostic tools. The plasmas generate, at low temperature, beams of atoms and radicals well-suited for surface treatment, cleaning, etching, deposition, and sterilization. Applications are in the 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 nanostucture 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
James F. Davis, Ph.D. (Northwestern U., 1981) 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
Ali Reza Khademhosseini, Ph.D. (MIT, 2005) Biomaterials, tissue engineering, organ-on-a-chip, stem cell engineering, biofabrication, micro- and nano-technology, biomedical devices
Yunfeng Lu, Ph.D. (U. New Mexico, 1998) Semiconductor manufacturing and nanotechnology
Vasilios I. Manousiouthakis, Ph.D. (Rensselaer, 1986) Process systems engineering: modeling, simulation, design, optimization, and control
Harold G. Menouque, Ph.D. (North Carolina State, 1987) Biomedical engineering, biosensors, nanotechnology
Stanley J. Osher, Ph.D. (New York U., 1966) Computational science, image processing, information science
Philippe Sautet, Ph.D. (U. Paris XI Orsay, France, 1989) First principles atomic scale simulations; quantum chemistry; applications to heterogeneous catalysis: active sites and reaction mechanisms, nanomaterials for depolulation and energy transformation, molecules at surfaces
Yi Tang, Ph.D. (Caltech, 2002) Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibotics/antitumor products

Professors Emeriti
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
Louis J. Igarra, Ph.D. (U. Minnesota, 1966) Regulation and modulation of NO production
Eldon L. Kruth, Ph.D. (Caltech, 1953) Molecular dynamics, thermodynamics, combustion, applications to air pollution control and combustion engines
Ken Nobe, Ph.D. (UCLA, 1966) Electrochemistry, corrosion, electrochemical kinetics, electrochemical energy conversion, electrodereposition of metals and alloys, electrochemical treatment of toxic wastes, bioelectrochemistry
Selim M. Senkan, Ph.D. (MIT, 1977) Reaction engineering, combinatorial catalysis, combustion, laser photionization, real-time detection, quantum chemistry

Assistant Professors
Nasim Annabi, Ph.D. (U. Sydney, Australia, 2010) Biomaterials, tissue engineering, 3D bioprinting, microfabrication, nanocomposite hydrogels for drug/gene delivery, surgical sealants/adhesives glues, conductive hydrogels for heart tissue regeneration
Yvonne Y. Chen, Ph.D. (Caltech, 2011) Synthetic biology, gene-circuit engineering, cell-based therapy, T-cell engineering
Carlos G. Morales-Guiol, Ph.D. (École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, 2016) Electrochemistry, renewable energy storage, nanotechnology, advanced energy materials, catalysis, CO2 utilization, process design, mass transport coupled to chemical transformations
Junyoung O. Park, Ph.D. (Princeton, 2016) Cancer metabolism, metabolic engineering, bioenergy, systems biology, metabolomics
Dante A. Simonetti, Ph.D. (U. Wisconsin-Madison, 2008) Heterogeneous catalysis and adsorption, catalytic reaction engineering and kinetics, design of reactive materials, materials characterization
Samarnava Srivastava, Ph.D. (Cornell, 2014) Soft materials, self-assembly, polymer chemistry and polymer physics, scattering rheology

Lower-Division Courses

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

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.

45. Biomolecular Engineering Fundamentals. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Recommended requisites: Chemistry 20A, 20L, 30A, 30L. Intended for those students who have not taken Life Sciences 2, 3, and Chemistry 153A. Fundamentals of modern biomolecular engineering. Topics include structure and function of biomolecules, central dogma of molecular biology, cellular information and energy processing, and experimental methods, with strong emphasis on applications in medicine, industry, and bioenergy. Letter grading.

99. Student Research Program. (1 to 2) Tutorial (supervised research or creative 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 a math and science (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper-Division Courses

100. Fundamentals of Chemical and Biomolecular Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20B, 20L (not enforced), Mathematics 32B (may be taken concurrently). Physical 1A. Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programming in MATLAB. Letter grading.


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

102A. Thermodynamics I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to thermodynamics of macroscopic and biological processes. Work, energy, heat, and first law of thermodynamics. Second law, extremum principles, entropy, and free energy. Ideal and real gases, properties of liquids. Letter grading.

102B. Thermodynamics II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to thermodynamics of macroscopic and biological processes. Work, energy, heat, and first law of thermodynamics. Second law, extremum principles, entropy, and free energy. Ideal and real gases, properties of liquids. Letter grading.

103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 103, 101C. Application of principles of heat, mass, and momentum transport to design and operation of separation processes such as distillation, gas absorption, filtration, and reverse osmosis. Letter grading. Ms. Sautet (Sp)

104A. Chemical and Biomolecular Engineering Laboratory I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisite: course 100. Enforced corequisite: course 101B. Recommended: course 102B. Investigation of basic transport phenomena in 10 predetermined experiments, collection of data for statistical analysis and individually written technical reports and group presentations. Design of performance of experiments. Concurrently scheduled with course 102B. Letter grading. Mr. Coury (Sp)

104B. Chemical and Biomolecular Engineering Laboratory II. (4) Lecture, four hours; laboratory, eight hours; outside study, four hours; other, two hours. Enforced requisite: courses 101C, 103, 104A. Course consists of four experiments in chemical engineering unit operations, each of two weeks duration. Students present their results written and orally. Written report includes sections on theory, experiment, equipment and process details, and error analysis. Presentation of student results in both written and oral form. Letter grading.

Mr. Simonetti (Sp)

104C. Semiconductor Processing. (3) 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.

Ms. Chang (Sp)

104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours; outside study, five hours. Enforced requisite: course 101C. Enforced corequisite: course 104CL. 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, and metallization. Hands-on experiment testing includes transistors, diodes, and capacitors. Letter grading.

Ms. Chang (Sp)


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

107. Process Dynamics and Control. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 101C, 103 (or C125), 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. Ms. Christofides (W)

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 103 (or C125), 104A. Emphasis of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purpose of designing chemical processes and evaluating alternatives. Letter grading. Mr. Morales-Guijo (W)

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Emphasis of chemical engineering fundamentals such as transport phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purpose of designing chemical processes and evaluating alternatives. Letter grading.

Mr. Morales-Guijo (Sp)

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Civil and Environmental Engineering M20 or Mechanical and Aerospace Engineering M20. Emphasis of chemical and biomolecular engineering examples used throughout to illustrate application of these methods. Use of MATLAB or Mathlab (programming environment) to write programs based on numerical methods to solve various problems arising in chemical engineering. Letter grading.

Mr. Christofides (F)

110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 102B. Principles and engineering applications of chemical and biochemical thermodynamics. Determination of partition function in terms of simple molecular models and spectroscopic data; nonideal gases; phase transitions and adsorption; nonequilibrium thermodynamics and coupled transport processes. Letter grading. (Not offered 2018-19)

C111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 102A, C125. Fundamentals of cryogenics and cryogenic science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C211. Letter grading. (Not offered 2018-19)

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

113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Enforced requisite: courses 101C, 102B. Integrated approach to air pollution, including concentration, atmospheric dispersion, standard, air pollution sources and control technology, and relationship of air quality to emission sources. Links air pollution to multimedia environmental assessment. Letter grading. (Not offered 2018-19)

CM114. Electrochemical Processes. (4) Formerly numbered C114. (Same as Materials Science CM163.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102B, Mechanical and Aerospace Engineering CM118, Materials Science 130. Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes. Primary emphasis on fundamental approach to design of electrochemical processes. Specific topics include electrochemical reactions on metal and semiconductor surfaces, electrodeposition, electroless deposition, electroosmosis, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course CM214. Letter grading.

Ms. Chang (Not offered 2018-19)

C115. Biochemical Reaction Engineering. (4) 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 of chemical engineering design and economic analysis of biological reactors. May be concurrently scheduled with course CM215. Letter grading.

Ms. Annabi (F)

C116. Surface and Interface Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to surfaces and interfaces of engineering materials, particularly catalytic surface and thin films for solid-state electronic devices. Topics include classical treatments of 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 devices. May be concurrently scheduled with course CM216. Letter grading.

Mr. Lu (Sp)


Mr. Cohen (Not offered 2018-19)


Mr. Manousiouthakis (Not offered 2018-19)

C121. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101A, 101C, 103. Fundamentals of membrane science and technology, with emphasis on separations.
C141. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 200A. Modern molecular biology techniques, protein and gene expression, DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and vaccine engineering. Concurrently scheduled with course CM245. Letter grading. Ms. Chen (F)

M153. Introduction to Micrascule and Nanoscoppe Manufacturing. (4) (Same as Bioengineering M15S, Electrical and Computer Engineering M153, and Mechanical and Aerospace Engineering M183B.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4A, 4BL. Introduction to general manufacturing methods, mechanisms, constraints, and microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various microfabrication and nanofabrication techniques that are currently being broadly applied in industry and academia, including various photolithography technologies, physical and chemical deposition methods, and physical and chemical etching methods. Hands-on experience for fabricating microstructures and nanostructures in modern cleanroom environment. Letter grading. Mr. Chou (F, Sp)

188. Special Courses in Chemical Engineering. (4) Seminar, one hour; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. May be repeated for credit with instructor change. Letter grading.

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

199. Directed Research in Chemical Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised independent 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 contracts required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F,W,Sp)

Graduate Courses

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

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 200 or Chemistry C223A or Physics 215A. Modern simulation techniques for classical molecular systems. Monte Carlo and molecular dynamics in various ensembles. Applications to liquids, solids, and polymers. Letter grading. (Not offered 2018-19)

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

C211. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamentals of cryogenics and cryoengineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of problems faced by the cryogenic engineer. Emphasis on selection of cryogenic systems and low-temperature heat exchangers for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading. Mr. Yuan (Not offered 2018-19)

C212. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for polymer development, 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. Cohen (W)

CM214. Electrochemical Processes. (4) (Formerly numbered C214.) (Same as Materials Science CM127.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102B, Mechanical and Aerospace Engineering 105A (or Materials Science 130). Fundamentals of electrochemistry engineering and introduction to electrochemical processes. Primary emphasis on fundamentals of electrochemistry processes. Specific topics include electrochemical reactions on metal and semiconductor surfaces, electrodeposition, electrodeless deposition, electrosynthesis, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course C114. Letter grading. Ms. Chang (Not offered 2018-19)

CM215. Biochemical Reaction Engineering. (4) (Same as Bioengineering M215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course C212. Introduction to biochemical engineering applications, including catalytic surfaces, industrial low-temperature processes. Basic ap-
Advanced Mass Transfer, (4) Lecture, four hours; outside study, eight hours. Requisite: course 101C. Advanced treatment of mass transfer, with applications to industrial separation processes, gas cleaning, pulmonary bioengineering, controlled release systems, and reactor design; molecular and constitutive theories of diffusion, interfacial transport, membrane transport, convective mass transfer, concentration boundary layers, turbulent transport. Letter grading. Mr. Srivastava (W)

C221. Membrane Science and Technology. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: 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/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 for applications, including nanotechnology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C121. Letter grading.

Mr. A. Rheden (Sp)


Mr. Manousiouthakis (Not offered 2018-19)

C228B. Stochastic Optimization and Control. (4) Lecture, four hours; outside study, seven hours. Introduction, K-algorithm, discrete and continuous control, constrained optimization, nonlinear control, stochastic systems, control problems, stochastic optimization, stochastic linear systems, and their applications. Letter grading. Ms. Chang (F)


Mr. Senkan (Not offered 2018-19)

C231. Molecular Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 106 or 110. Analysis and design of molecular-beam systems. Molecular-beam sampling of reactive mixtures in combustion chambers or gas jets. Molecular-beam studies of gas-surface interactions, including energy accommodation and heteronuclear collisions. Applications to air pollution control and catalysis. Letter grading. (Not offered 2018-19)


Mr. Senkan (Not offered 2018-19)

C233. Frontiers in Biotechnology. (2) Lecture, one hour. Requisite: Life Sciences 3. Integration of science and business in biotechnology. Academic research leading to licensing and founding of companies that turn research breakthroughs into marketable products. Invited lecturers from academia and industry. Discussion and presentation of biotechnology from combination of science, engineering, and business points of view. S/U or letter grading. (Not offered 2018-19)

C234. Plasma Chemistry and Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: designed for graduate chemistry or engineering students. Application of chemistry, physics, and engineering principles to design and operation of plasma and ion-beam reactors used in etching, deposition, oxidation, and cleaning of materials. Examination of atomic, molecular, and ionic phenomena involved in plasma and ion-beam processing of semiconductors, etc. Letter grading. Ms. Chang (Not offered 2018-19)

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

C236. Chemical Vapor Deposition. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 210, C216. Chemical vapor deposition is widely used to deposit thin films that comprise microelectronic devices. Topics include reactor design, transport phenomena, gas and surface chemical kinetics, structure and composition of deposited films, and relationship between process conditions and film properties. Letter grading. (Not offered 2018-19)

C238. Fundamentals of Aerosol Technology. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 101C. Technology of particle/gas systems with applications to gas cleaning, combustion, production of nanoparticles, catalysis, and more. Particle transport and deposition, optical properties, experimental methods, dynamics and control of particle formation processes. Concurrently scheduled with course C140. Letter grading. (Not offered 2018-19)

C241. Chemical Catalysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Selected topics in chemical catalysis and heterogeneous catalysis. Letter grading. (Not offered 2018-19)

C242A. 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 therapeutic and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C342. Letter grading.

Ms. Segura (Not offered 2018-19)

CM225. Bioseparations and Bioprocess Engineering. (4) (Same as Bioengineering M225.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: 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. Applications to biotechnological reactors. Concurrently scheduled with course C125. Letter grading. Ms. Annabi (Sp)

C227. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM227.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: Chemistry 153A. Engineering microorganisms for complex phenotype is 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 biochemistry, protein structure, and biological regulations and are aided by tools for molecular biology, and molecular biology. Fundamentals of metabolic biochemistry, protein structure, and bioinformatics. Use of systems modeling for metabolic networks to design microorganisms for energy applications. Concurrently scheduled with course CM127, S/U or letter grading. (Not offered 2018-19)

C228. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 222A. Properties of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and thermochemical cycling. Identification of bottlenecks in hydrogen production, including hydrogen combustion and hydrogen fuel cells. Concurrently scheduled with course C128. Letter grading.

Mr. A. Rheden (Sp)


Mr. Senkan (Not offered 2018-19)

C254. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM254.) Lecture, four hours; discussion, one hour; outside study, seven hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis, and protein engineering. DNA-based diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading. Ms. Chen (F)

246. Systems Biology: Intracellular Network Identification and Analysis. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course CM245 or M245. Data from genome sequencing, large-scale expression, and other high-throughput techniques provide bases for systems identification and analysis. Discussion of gene-metabolic network synthesis. Letter grading. Mr. Liao (Not offered 2018-19)

250. Computer-Aided Chemical Process Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 108B. Application of optimization methods in chemical process design; computer aids in process engineering; process modeling; systematic flow sheet invention; process synthesis; optimal design and operation of large-scale chemical processing systems. Letter grading. Ms. Chen (Not offered 2018-19)

chonics, Stress constitutive equations. Rheology of polymeric liquids and dispersed systems. Applications in viscometry, polymer processing, bioengineering, oil recovery, and drag reduction. Letter grading.

Mr. Cohen (Not offered 2018-19)

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

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

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

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


283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M280A, M282A. Designed for graduate students. Introduction to advanced dynamical analysis and controller synthesis methods for nonlinear infinite dimensional systems. Topics include (1) linear operator and stability theory (basic results on Banach and Hilbert spaces, semigroup theory, convergence theory in function spaces), (2) nonlinear model reduction (linear and nonlinear Galerkin method, proper orthogonal decomposition), (3) nonlinear and robust control of nonlinear hyperbolic and parabolic partial differential equations (PDEs), (4) applications to transport-reaction processes. Letter grading.

Mr. Christofides (Not offered 2018-19)


Mr. Manoussouthis (Not offered 2018-19)
Civil and Environmental Engineering

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Shailie Mahendra, Ph.D. (Henry Samueli Fellow)
Gaurav Sant, Ph.D. (Henry Samueli Fellow)
Jian Zhang, Ph.D.

Assistant Professors
Mathieu Bauchy, Ph.D.
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Sanjay Mohanty, Ph.D.

Adjunct Professors
Robert E. Kayen, Ph.D., P.E.
Michael J. McGuire, Ph.D., P.E., NAE
George Mylonakis, Ph.D., P.E.
Thomas Sabol, Ph.D., S.E.

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

Civil and Environmental Engineering

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

Learning Outcomes

The Civil Engineering major has the following learning outcomes:

• Understanding of, and ability to apply, basic mathematical and scientific concepts that underlie the field

• Ability to contribute meaningfully to design projects

• Critical thinking skills, problem-solving abilities, and familiarity with computational procedures essential to the field

• Ability to work productively as a member of a team

• Effective oral and written communication skills

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 (or
Structural/earthquake engineering graduate students visit the Metropolis high-rise residential project Tower 3 and the KPFF Consulting Engineers office in downtown Los Angeles, California.

Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C, 4A; one natural science course selected from Civil and Environmental Engineering 585L, Earth, Planetary, and Space Sciences 3, 15, 16, 17, 20, Environmental 12, Life Sciences 1, 2, 7A, 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 91, 102, 103, C104 (or Materials Science and Engineering 104), 108, 110, 120, 135A, 150, 153, Mechanical and Aerospace Engineering 103; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; and at least eight major field elective courses (32 units) from the lists below with at least two design courses, one of which must be a capstone design course and two of which must be laboratory courses. The laboratory courses must be taken from two distinct areas. Courses applied toward the required course requirement may not also be applied toward the major field elective requirement.

Civil Engineering Materials: Civil and Environmental Engineering C104, C105, C182; laboratory course: 108L.

Environmental Engineering: Civil and Environmental Engineering 154, 155, 164, M165, M166; laboratory courses: 156A, 156B; capstone design courses: 157B, 157C.

Geotechnical Engineering: Civil and Environmental Engineering 125; laboratory courses: 128L, 129L; design courses: 121, 123 (capstone).

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

Structural Engineering and Mechanics: Civil and Environmental Engineering 125, 130, 135B, M135C, C137, 142; laboratory courses: 108L, 135L, 140L; design courses: 141, 143, 144 (capstone), 147 (capstone).

Transportation Engineering: Civil and Environmental Engineering 180, 181, C182.

Additional Elective Options: Courses selected from an approved list available in the UCLA Samueli Office of Academic and Student Affairs. Note: both 128L and 129L may be taken to satisfy the two-laboratory-course requirement.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

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, Environmental 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 with 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 in the minor. Successful completion of the minor is indicated on the transcript and diploma.

Graduate Study

For information on graduate admission, see Graduate Programs on page 25.

The following introductory information is based on 2018–19 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. 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

There are two plans of study that lead to the M.S. degree: the capstone plan (also known as comprehensive examination) and the thesis plan. At least nine courses (36 units) 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 capstone (comprehensive examination) plan, 500-series courses may not be applied toward the nine-course requirement.
Courses completed outside of the department must be equal in rigor and related to the civil and environmental engineering program of study and are recommended to be quantitative in nature. In addition, M.S. students must attend the Civil and Environmental Engineering 200 seminar each quarter. Graduate students must meet two grade-point average requirements to graduate—a minimum 3.0 GPA in all coursework and a minimum 3.0 GPA in all 200-level coursework applied toward the degree. All courses counting toward the nine-course requirement, except for 598, must be taken for a letter grade.

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. Courses not listed below may be completed toward the course requirement if pre-approved by the faculty adviser and student affairs officer.

Undergraduate Courses. No lower-division courses (1-99) may be applied toward graduate degrees.

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, C205, 226, 253, 258A, 261B, M262A, 263A, 266, 267.

**Other Elective Courses.** Remaining courses (at least two) must be selected from Chemical Engineering 102A, 102B, 200, C219, 223, 230, 270, Chemistry and Biochemistry 103, 110A, 110B, 113A, C213B, C215A through 215D, C223A, C223B, 225, C226A, C275, 276B, 277, Civil and Environmental Engineering 110, M135C, 153, 154, 155, 157A, 157B, 157C, 157L, 163, 225, 250A through 250D, 251C, 251D, 252, 253, 254A, 255A, 255B, 256, 260, 261B, M262A, 263A, 263B, 266, or other elective courses approved by the academic adviser and graduate adviser. Electives in the fields of biostatistics/statistics, chemical engineering, chemistry and biochemistry, computer science, Earth and space sciences, electrical and computer engineering, and environmental health sciences are commonly approved to satisfy course requirements. No more than two courses may be applied outside of Civil and Environmental Engineering unless pre-approved for exceptional circumstances. No more than two undergraduate courses may be applied toward the nine-course requirement unless pre-approved for exceptional circumstances.

**Environmental and Water Resources Engineering**

**Required Preparatory Courses.** Chemistry and Biochemistry 20A, 20B, 20L, Civil and Environmental Engineering 151 or 153; Mathematics 32A, 32B, 33B (or Mechanical and Aerospace Engineering 82); Mechanical and Aerospace Engineering 103; Physics 1A, 1B, 4AL.

**Environmental and Water Resources Engineering Option.** Required: Two courses from Civil and Environmental Engineering 250A through 250D; two courses from 254A, 255A, 255B, 266. Select the remaining courses (nine total for the capstone [comprehensive examination] option and seven total for the thesis option) from the approved elective list or obtain approval for other electives.

**Environmental Engineering Option.** Required: Civil and Environmental Engineering 254A, 255A, 255B, 266; one course from 250A through 250D. Select the remaining courses (nine total for the capstone [comprehensive examination] option and seven total for the thesis option) from the approved elective list or obtain approval for other electives.

**Hydrology and Water Resources Engineering Option.** Required: Civil and Environmental Engineering 250A through 250D; one course from 254A, 255A, 255B, or 266. Select the remaining courses (nine total for the capstone [comprehensive examination] option and seven total for the thesis option) from the approved elective list or obtain approval for other electives.

**Major Field Elective Courses.** One course from 254A, 255A, 255B, or 266. Select the remaining courses (nine total for the capstone [comprehensive examination] option and seven total for the thesis option) from the approved elective list or obtain approval for other electives.

**Elective Courses.** Undergraduate—no more than two courses from Civil and Environmental Engineering M135C, C137, 143, and either 141 or 142 ( whichever was not used as a requisite for graduate courses); geological area—Civil and Environmental Engineering 220, 221, 222, 223, 225, 227; general graduate—Civil and Environmental Engineering M230A, M230B, M230C, 232, 233, 235B, 235C, 236, M237A, 238, 241, 243A, 243B, 244, 245, 247, Mechanical and Aerospace Engineering 269B.

**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.** Civil and Environmental Engineering 225, 226, 227, 228, C239, 245.

**Other Elective Courses.** Other elective courses may be taken with prior approval from the faculty adviser.

**Structural/Earthquake Engineering**

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

**Required Graduate Courses.** Civil and Environmental Engineering 235A, C239, 246, and at least three courses from 235B, 241, 243A, 243B, 244, 245, 247.

**Elective Courses.** Undergraduate—no more than two courses from Civil and Environmental Engineering M135C, C137, 143, and either 141 or 142 ( whichever was not used as a requisite for graduate courses); geological area—Civil and Environmental Engineering 220, 221, 222, 223, 225, 227; general graduate—Civil and Environmental Engineering M230A, M230B, M230C, 232, 233, 235B, 235C, 236, M237A, 238, 241, 243A, 243B, 244, 245, 247, Mechanical and Aerospace Engineering 269B.

**Structural Mechanics**

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


**Elective Courses.** Undergraduate—maximum of two courses from Civil and Environmental Engineering M135C, C137, 137L; graduate—Civil and Environmental Engineering M230B, M230C, 233, 235C, 238, 244, 246, 247, Mechanical and Aerospace Engineering 269B.

**Structures and Civil Engineering Materials**

**Required Preparatory Courses.** General chemistry and physics with laboratory exercises, multivariate calculus, linear algebra, and differential equations, introductory thermodynamics, structural analysis (Civil and Environmental Engineering 135A, 135B), steel or concrete design ( course 141 or 142). Other undergraduate preparation could include Civil and Environmental Engineering C104, 120, 121, 140L, and Materials Science and Engineering 104.
**Required Graduate Courses.** Civil and Environmental Engineering C204, M230A (or 243A), 235A, C282.

**Elective Courses.** At least one course from civil engineering materials (Civil and Environmental Engineering 226, 253, 258A, 261B, M262A, 266, or 267) and if M230A is selected, one course from structural mechanics (M230B, M230C, 232, 236, or M237A) or if 243A is selected, one course from structural/earthquake engineering (241, 243B, 244, 245, 246, or 247).


**Capstone (Comprehensive Examination) Plan.**

In addition to the course requirements, a comprehensive examination is administered that covers the subject matter contained in the program of study. The examination may be offered in one of the following formats: (1) a portion of the doctoral written preliminary examination, (2) examination questions offered separately on final examinations of common department courses to be selected by the comprehensive examination committee, or (3) a written and/or oral examination administered by the committee. Committees for the capstone plan consist of at least three faculty members. 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.

The normative duration for full-time students in the M.S. programs is three quarters. The maximum time allowed for completing the M.S. degree is three years from the time of admission to the M.S. program in the School. Each quarter, students must make satisfactory progress toward their degree. Quarters taken on an approved leave of absence do not count toward the three year time limit.

**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 preliminary examination. The basic program of study for the Ph.D. degree is built around one major field and one super-minor field or two minor fields. A super-minor field is comprised of a body of knowledge equivalent to five courses, at least three of which are at the graduate level. When two minor fields are selected, 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. The minimum acceptable grade-point average for the minor field is 3.25. 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. A minimum 3.25 grade-point average is required in all coursework. In addition, Ph.D. students must attend the Civil and Environmental Engineering 200 seminar each quarter until they advance to candidacy.

Students who have completed graduate-level coursework prior to entering a UCLA doctorate program may apply coursework toward one of the following: Ph.D. major field, one minor, or super-minor. At least 50 percent of coursework applied toward the Ph.D. program must be completed at UCLA, unless a petition has been approved by the department.

**Written and Oral Qualifying Examinations.**

After mastering the body of knowledge defined in the major field, students take a written preliminary examination that should be completed within the first two years of full-time enrollment in the Ph.D. program. Students may not take the examination more than twice.

After completing the written preliminary examination and/or starting the second year of the Ph.D. program, all Ph.D. students are required to make a public presentation once per year (summer through spring) each year of the program. The presentation may be delivered to various audiences (research group, Civil and Environmental Engineering Department, conference) and must be publicized to the Civil and Environmental Engineering Department in advance of the presentation date. Students will provide documentation of presentations annually to the Student Affairs Office. The qualifying oral examination (prospectus, final oral examination (defense), and poster presentations are eligible to fulfill the annual presentation requirement.

After passing the written preliminary examination and substantially completing all minor field coursework, 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. The student must confirm with the committee the expectations of deliverables for the prospectus including, but not limited to, written documents and an oral presentation.

Students nominate a doctoral committee prior to taking the University Oral Qualifying Examination. Students are required to meet with committee members once per year (summer through spring) after advancement to candidacy until graduation. Meetings may be one on one or as a group and members may participate remotely. Students will provide documentation of meetings annually to the Student Affairs Office.

**Note: Doctoral Committees.** A doctoral committee consists of a minimum of four members. Two members, including the chair, must hold full-time faculty appointments in the department. For a full list of doctoral committee regulations, see the Graduate Division Standards and Procedures for Graduate Study at UCLA.

**Advancement to Candidacy.**

Students are advanced to candidacy upon successful completion of the written preliminary and oral qualifying examinations.
Doctoral Dissertation
Every doctoral degree program requires the completion of an approved dissertation that demonstrates the student's ability to perform original, independent research and constitutes a distinct contribution to knowledge in the principal field of study.

Final Oral Examination
A final oral examination, or defense of dissertation, is required for all students in the program.

Time-to-Degree
The normative duration for full-time students in the Ph.D. program, after completing a M.S. degree, is 12 quarters. The maximum time allowed for completing the Ph.D. degree, after completing the M.S. degree, is 24 quarters. Each quarter, students must maintain satisfactory academic progress toward their degree. Quarters taken on an approved leave of absence do not count toward the time limit.

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 nanoscale to macroscale. Special efforts are devoted toward developing low-cement factor cements and concretes, reducing the carbon footprint of construction materials, and increasing the service life of civil engineering infrastructure.

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

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

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

Structures (Structural Mechanics and Earthquake Engineering)
Research in structural mechanics is directed toward improving the ability of engineers to understand and interpret structural behavior through experiments and computer analyses. Areas of special interest include computer analysis using finite-element techniques, computational mechanics, structural dynamics, nonlinear behavior, plasticity, micromechanics of composites, damage and fracture mechanics, structural optimization, probabilistic static and dynamic analysis of structures, and experimental stress analysis. Designing structural systems capable of surviving major earthquakes is the goal of experimental studies on the strength of full-scale reinforced concrete structures, computer analysis of soils/structural systems, design of earthquake resistant masonry, and design of seismic-resistant buildings and bridges. Teaching and research areas in structural/earthquake engineering involve assessing the performance of new and existing structures subjected to earthquake ground motions. Specific interests include assessing the behavior of reinforced concrete buildings and bridges, as well as structural steel, masonry, and timber structures. Integration of analytical studies with laboratory and field experiments is emphasized to assist in the development of robust analysis and design 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
Engineering Geomatics
Engineering Geomatics is a field laboratory that teaches basic and advanced geomatics techniques including light detection and ranging (LiDAR) imaging, geo-referencing using total station and differential global positioning system (GPS) equipment, and integration of measurements with LiDAR mapping software and Google Earth. Experiments are conducted on campus.

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 gener-
ating 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. In the Advanced Soil Mechanics Laboratory, students see demonstrations of cyclic soil testing techniques including triaxial and direct simple shear, and advanced data acquisition and processing.

**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.

**Laboratory for the Chemistry of Construction Materials (LC²)**

Laboratory for the Chemistry of Construction Materials (LC²) research efforts are directed towards development and design of sustainable, low-carbon-dioxide-footprint materials for infrastructure construction applications. To this end, its research group develops fundamental constituent chemistry-microstructure-engineering performance descriptors of cementitious materials to correlate and unify the fundamental variables that describe the overall response of the material.

These efforts are directed toward addressing the practical needs of the wider construction community and developing “new concretes” for the next generation of infrastructure construction applications. The overall research theme aims to rationalize use of natural resources in construction, promote environmental protection, and advance the cause of ecological responsibility in the concrete construction industry.

**Laboratory for the Physics of Amorphous and Inorganic Soils (PARISlab)**

Laboratory for the Physics of Amorphous and Inorganic Soils (PARISlab) research focuses on improving materials of engineering and industrial relevance. Its goal is to understand composition-nano- and microstructure property relationships in materials at a fundamental level. To this end, it uses a computational physical/material science approach supported by experiments.

In strong collaboration with the Laboratory for the Chemistry of Construction Materials (LC²), PARISlab works to establish a new paradigm in civil engineering by tackling the sustainability of infrastructure materials at different scales, from atoms to structures.

**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 facility is 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
Youself Bozorgnia, Ph.D., P.E. (UC Berkeley, 1981) Structural engineering, earthquake engineering, engineering seismology
Scott J. Brandenberg, Ph.D., P.E. (UC Davis, 2005) Geotechnical earthquake engineering, soil-structure interaction, liquefaction, data acquisition and processing, numerical analysis
J.R. DeShazo, Ph.D. (Harvard, 1997) Regulatory policy, institutional design, environmental economics, energy economics, electric vehicles
Eric M.V. Hoek, Ph.D. (Yale, 2001) Physical and environmental chemical processes, colloidal and interfacial phenomena, environmental membrane separations, bio-adhesion and bio-fouling
Jennifer A. Jay, Ph.D. (MIT, 1999) Aquatic chemistry, environmental microbiology
Dennis P. Lettenmaier, Ph.D., NAE (U. Washington, 1975) Hydrologic modeling and prediction, hydrology-climate interactions, hydrologic change
Steven A. Margulis, Ph.D. (MIT, 2002) Surface hydrology, hydrometeorology, remote sensing, data assimilation
Ali Mosleh, Ph.D., NAE (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
John W. Wallace, Ph.D., P.E. (UC Berkeley, 1988) Earthquake engineering, design methodologies, seismic evaluation and retrofit, large-scale testing laboratory and field testing
William W-G. Yeh, Ph.D., NAE (Stanford, 1967) Hydrology and optimization of water resources systems

Professors Emeriti
Stanley B. Dong, Ph.D., P.E. (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, 1961) Structural analysis, structural mechanics, automated optimum structural design, including reliability-based design
Michael E. Fourney, Ph.D., P.E. (Caltech, 1963) Experimental mechanics, special emphasis on application of modern optical techniques
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
Richard L. Pierne, 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. (UC, 1961) Systems analysis and design, problem-solving and decision-making models
Lawrence G. Sein, Ph.D., S.E. (UC Berkeley, 1967) Reinforced concrete, earthquake engineering
Keith D. Stobbenbach, Ph.D., P.E. (MIT, 1971) Environmental fluid mechanics, fate and transport of pollutants, dynamics of particles
Mladen Vucetic, Ph.D. (Rensselaer, 1986) Geotechnical engineering, soil dynamics, geotechnical earthquake engineering, experimental studies of static and cyclic soil properties

Associate Professors
David Jassby, Ph.D. (Duke, 2011) Water treatment and desalination, membrane separation processes, membrane material fabrication, electrochemistry, environmental applications of nanotechnology
Shally Mahendra, Ph.D. (UC Berkeley, 2007) Environmental microbiology, biodegradation of groundwater contaminants, microbial-nanomaterial interactions, nanotoxicology, applications of molecular biological and isotopic tools in environmental engineering
Gaurav Sant, Ph.D. (Caltech, 2009) Cementitious materials and porous media with focus on chemistry-structure-property relationships and interfacial thermodynamics of materials
Jian Zhang, Ph.D. (UC Berkeley, 2002) Earthquake engineering, structural dynamics and mechanics, seismic protective devices and strategies, soil-structure interaction, and bridge engineering

Assistant Professors
Henry V. Burton, Ph.D., S.E. (Stanford, 2014) Performance-based earthquake engineering, design seismic, evaluation and retrofit, enhanced seismic performance systems, building community resilience
Timu W. Gallon, Ph.D. (UC Irvine, 2012) Urban coastal flood prediction, wave runup and overtopping, coastal hazards, sea level rise, flood control infrastructure and mitigation methods, nearshore remote sensing and observation
Sanjay Mohanty, Ph.D. (U. Colorado Boulder, 2011) Effect of water change on water quality and quantity; sustainable urban development at the water-energy nexus; transport of contaminants and colloids in the subsurface and groundwater; stormwater capture, treatment, and re-use; bioremediation

Civil and Environmental Engineering / 55

Adjunct Professors
Robert E. Kayen, Ph.D., P.E. (UC Berkeley, 1993) Geomatics and terrestrial photogrammetric modeling, geotechnical earthquake engineering, engineering geology, applied geophysics
Michael J. McGuire, Ph.D., P.E., NAE (Drexel, 1977) Control of tracers in organism in water treatment including activated carbon
George Mylonakis, Ph.D., P.E. (UNY Buffalo, 2005) Soil mechanics and dynamics, earthquake engineering, geomechanics, stress wave propagation, foundation engineering
Thomas Sabol, Ph.D., S.E. (UCLA, 1985) Seismic performance and structural design issues for steel and concrete seismic force resisting systems; application of probabilistic methods to earthquake damage quantification

Adjunct Associate Professors
Donald R. Kendall, Ph.D., P.E. (UCLA, 1989) Hydraulics, groundwater hydrology, advanced engineering economics, stochastic processes
Issam Najm, Ph.D., P.E. (U. Illinois Urbana-Champaign, 1990) Water chemistry; physical and chemical processes in drinking water treatment

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.
2. Environmental engineering M20. (Formerly numbered 101.) Lecture, four hours; service learning, two hours; outside study, nine hours. Service related to climate change, water quality, and ecosystem health. Topics include carbon and nutrient cycling, hydrologic cycle, ecosystem structure and services, biodiversity, basic aquatic chemistry, and impacts of climate change on ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading.

90. Advanced Statics. (4) (Formerly numbered 101.) Lecture, four hours; service learning, two hours; outside study, nine hours. Service related to climate change, water quality, and ecosystem health. Topics include carbon and nutrient cycling, hydrologic cycle, ecosystem structure and services, biodiversity, basic aquatic chemistry, and impacts of climate change on ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading.

19. Civil and Environmental Engineering / 55

Letter grading.

91. Statics. (4) Formerly numbered 101. Lecture, four hours; discussion, two hours; outside study, six hours. Factory in which it is designed and constructed. Role of civil engineers in infrastructure development and preservation. P/NP grading.

80SL. Climate Change, Water Quality, and Ecosystem Functioning. (5) Lecture, four hours; service learning, two hours; outside study, nine hours. Service related to climate change, water quality, and ecosystem health. Topics include carbon and nutrient cycling, hydrologic cycle, ecosystem structure and services, biodiversity, basic aquatic chemistry, and impacts of climate change on ecosystem functioning and water quality. Participation in series of science education projects to elementary or middle school audience. Letter grading.
Upper-Division Courses

102. Dynamics of Particles and Bodies, (2) Lecture, two hours; discussion, two hours; outside study, six hours. Requisites: course 91, Physics 1B. Introduction to fundamentals of dynamics of single particles, systems of particles, and rigid bodies. Topics include kinematics and kinetics of particles, work and energy, impulse and momentum, multi- particles systems, kinematics and kinetics of rigid bodies in two and three-dimensional motions. Letter grading.

Mr. Bauchy (W)

103. Applied Numerical Computing and Modeling in Civil and Environmental Engineering, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course M20 (or Computer Engineering 31), Mathematics 33B or Mechanical and Aerospace Engineering 82 (either may be taken concurrently). Introduction to numerical computing with specific applications to civil and environmental engineering. Topics include error and computer arithmetic, root finding, curve fitting, numerical integration and differentiation, solution of systems of linear and nonlinear equations, numerical solution of ordinary and partial differential equations. Letter grading.

Mr. Margulis, Mr. Taciroglu (Sp)


Mr. Sant (W)


Mr. Bauchy (Sp)


Mr. Bauchy, Ms. Zhang (W/Sp)


Mr. Ju (W)

110. Introduction to Probability and Statistics for Engineers, (4) Lecture, four hours; discussion, one hour (when scheduled); outside study, seven hours. Requisites: Mathematics 32A, 33A. Recommended: course M20. Introduction to basic concepts and applications of probability and statistics in civil engineering, with focus on how these concepts are used in experimental design and sampling, data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distributions, functions of random variables, estimating parameters from observational data, regression examination’s testing, and Bayesian concepts. Letter grading.

Ms. Jay (Sp)

120. Principles of Soil Mechanics, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 121. Foundation for structures and as material of construction. Soil formation, classification, physical and mechanical properties, soil compaction, earth pressures, consolidation, and shear strength. Letter grading.

Mr. Brandenberg (F)

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

Mr. Stewart (W)

123. Advanced Geotechnical Design, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 121. Analysis and design of earth dams, including seepage, piping, and slope stability analyses. Case history studies involving landslides, settlement, and expansive soil problems, and design of repair methodologies for these problems. Emphasis on preparation of professional engineering documents such as proposals, work acknowledge- ments, figures, plans, and reports. Letter grading.

Mr. Brandenberg (Sp)


Mr. Stewart (Not offered 2018-19)

128L. Soil Mechanics Laboratory, (4) Lecture, one hour; laboratory, six hours; outside study, five hours. Requisite or corequisite: course 120. Laboratory experiment designed to obtain soil parameters required for assigned design problems. Soil classification, grain size distribution, Atterberg limits, specific gravity, compaction, expansion index, consolidation, shear strength determination. Design of foundation problems, laboratory report writing. Letter grading.

Mr. Brandenberg (W)


Mr. Stewart (Sp)

130. Elementary Structural Mechanics, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 101 or course 137. Stress and strain, phenomenological material behavior, ex- tension, bending, and transverse shear stresses in beams with general cross-sections, shear center, de- developed beams, torsion, bending, column buckling, instability and failure. Letter grading.

Mr. Ju (Sp)

135A. Elementary Structural Analysis, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses M20 or Computer Science 31. Introduction to structural analysis: classification of structural elements; anal- ysis of statically determinate trusses, beams, and frames; deficiencies in elementary structures; virtual work; moment distribution. Letter grading.

Mr. Ju (F)

135B. Intermediate Structural Analysis, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 130 or course 137. Matrix formulation of trusses and frame structures using matrix methods; matrix force methods; matrix displacement method; analy- sis concepts based on theorem of virtual work; mo- ment distribution. Letter grading.

Mr. Taciroglu, Mr. Wallace (W)

M135C. Introduction to Finite Element Methods. (4) (Same as Mechanical and Aerospace Engineering M168). Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: courses M20, 135A. Introduction to fundamental concepts of finite element methods (FEM) and applications to structural and soil mechanics and heat transfer. Matrix structural analysis: weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software; geometric and analytical modeling; preprocessing and postpro- cessing techniques; term projects with computers.

Mr. Taciroglu (Sp)

135L. Structural Design and Testing Laboratory, (4) Lecture, two hours; laboratory, five hours; outside study, five hours. Requisites: courses M20, 135A. Limited enrollment. Computer-aided optimum de- sign, construction, instrumentation, and small- scale model structure. Use of computer-based data acquisition and interpretation systems for compar- ison of experimental and theoretically predicted be- havior. Letter grading.

Mr. Burton, Mr. Wallace (F/Sp)

C137. Elementary Structural Dynamics, (4) (Formerly numbered 137). Lecture, four hours; discus- sion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics course for civil engineering students. Elastic free and forced vi- brations of single degree of freedom systems, intro- duction to response history and response spectrum analysis approaches for single and multidegree of freedom systems. Axial, bending, and torsional vibra- tion of beams. Concurrency scheduled with course C239. Letter grading.

Mr. Taciroglu (F)

137L. Structural Dynamics Laboratory, (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisites: courses M20, 135B. Selected topics from Structural Dynamics 137L. Cali- bration of instrumentation for dynamic measure- ments. Determination of natural frequencies and damping factors from free vibrations. Determination of eigenvalues and eigenvectors for structures and damping factors from forced vibrations. Dynamic similitude. Letter grading.

Mr. Wallace (Not offered 2018-19)

140L. Structural Components and Systems Testing Laboratory, (4) Lecture, two hours; labora- tory, six hours; outside study, four hours. Enforced requisites: course 142. Comparison of experimental
results with analytical results and code requirements to assess accuracies and limitations of applicable procedures used in structural design. Members include architects, engineers, and other design professionals. Letter grading. Ms. Jay (W)

143. Design of Prestressed Concrete Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: courses 135A, 142. Limited enrollment. Design considerations used for reinforced concrete beams, columns, slabs, and walls. Specialized topics include analysis and design of prestressed concrete structures. Development of skills for written and oral presentations. Letter grading. Mr. Wallace (Not offered 2018-19)

154. Chemical Fate and Transport in Aquatic Environments. (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 qualitative problems solved considering both reaction and transport of chemicals in environmental systems. Letter grading. Ms. Jay (W)

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

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

156B. Environmental Engineering Unit Operations and Processes Laboratory. (4) Lecture, two hours; laboratory, four hours; outside study, four hours. Required: courses 153B, 141. Role of structural engineer, architect, and other design professionals in design process. Development of architectural and structural design of tall buildings. Influence of building code, zoning, and finance. Advantages and limitations of different structural systems. Development of structural system design and computer model for architectural design. Mr. Stenstrom (W)

150. Geology of California, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required: course 20M (or Computer Science 31), Mechanical and Aerospace Engineering 103. Sequence and relative attitudes of spheric processes, water and energy balance, radiation, precipitation formation, infiltration, evaporation, vegetation transpiration, groundwater flow, storm runoff, and flood processes. Letter grading. Mr. Margulis (F)

151. Introduction to Water Resources Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 150 or 151. Introduction to hydrologic modeling. Topics selected from areas of (1) open-channel flow, including one-dimensional streamline flow and unsteady flow, (2) flow and water distribution systems, (3) rainfall-runoff modeling, and (4) groundwater flow and contaminant transport modeling, with focus on use of industry and/or research software models with locally relevant applications. Letter grading. Ms. Gallien (Not offered 2018-19)

157B. Design of Water Treatment Plants. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 156A. Water and wastewater treatment systems. Design of treatment processes, selection of design parameters, and cost estimation. Letter grading. Mr. Stenstrom (W)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 155. Collection, compaction, and interpretation of data for quantification of components of hydrologic cycle, including precipitation, evaporation, infiltration, and runoff, and methods and parameters for development, construction, and application of analytical models for selected problems in hydrology and water resources. Letter grading. Mr. Mohanty (F)

164. Hazardous Waste Site Investigation and Remediation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: courses 150, 153, Mechanical and Aerospace Engineering 103. Overview of historical waste types and current disposal methods, methods to measure and model subsurface flow and contaminant transport in subsurface. Design project illustrating remedial investigation and feasibility study letter grading. Mr. Olsuemich (W)

M165. Environmental Nanotechnology: Implications and Applications. (4) Same as Engineering M103.) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: Engineering M101. Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include interdisciplinary areas of chemical, physical, and biological properties of nanomaterials, (2) trans- port, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nano- technology for energy and water production, plus en- vironmental 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. Enforced requisite: course 153. Microbial cell and its metabolic capabilities, microbial genet- ics and its potentials, growth of microbes and ki- netics of growth, microbial ecology, microbial diversity, mi- crobiology of wastewater treatment, probing of microbes, public health microbiology, pathogen control. Letter grading. Ms. Mahendra (W)

M166L. Environmental Microbiology and Biotechnology Laboratory. (4) Same as Environmental Health Sciences M166L.) Laboratory, two hours; outside study, two hours. Corequisite: course M166. General laboratory practice within environmental micro- biology, sampling of environmental samples, clas- sical and modern molecular techniques for enumera- tion of microbes from environmental samples, tech- niques for detection of microbial activity in environmental samples, and approaches for studying environmental biotechnology. Letter grading. Ms. Mahendra (Not offered 2018-19)
170. Introduction to Construction Management. (4) Lecture, four hours; discussion, one to two hours; outside study, six hours. Introduction to construction management theory, management, and techniques. Implementation of exercises from academic texts and real project case studies. Discussion of building components, project delivery methods, document control, critical path methods, bidding, labor management, project evaluation, estimating, sustainability, and cost controls. Letter grading. Mr. Sant (W)

180. Introduction to Transportation Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for juniors/senior Civil Engineering and Environmental Engineering students. General characteristics of transportation systems, including streets and highways, rail, transit, air, and water. Capacity considerations, including planning, design, and construction. Components of roadway design, including horizontal and vertical alignment, cross sections, 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/senior Civil Engineering and Environmental Engineering students. General characteristics of transportation systems, including streets and highways, rail, transit, air, and water. Capacity considerations, including planning, design, and construction. Components of roadway design, including horizontal and vertical alignment, cross sections, 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 requisites: courses C104, 108, 120, Materials Science 104. Correlation, analysis, and metrication of aspects of pavement design, including material selection, load and service life. Special attention to aspects of pavement distress/serviceability and factoring of these into metrics of pavement performance. Discussion of potential choices of pavement materials (e.g., asphalt and 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 pavement design. Concurrently scheduled with course C205. Letter grading. Mr. Brandenberg (F)

188. Special Courses in Civil and Environmental Engineering. (4) Lecture, to be arranged; outside study, to be arranged. Special topics in civil engineering for graduate students taught on an 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. (FW,Sp)

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

199. Directed Research in Civil and Environmental Engineering. (2 to 8) Tutorial, to be arranged and transmitted to juniors/senior. 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; contact with Office of Academic and Student Affairs. Letter grading.

Graduate Courses

200. Civil and Environmental Engineering Graduate Seminar. (2) Seminar, four hours; outside study, two hours. Various topics in civil and environmental engineering that may include earthquake engineering, environmental engineering, geotechnical engineering, hydrology and water resources engineering, geotechnical engineering, and structural mechanics. May be repeated for credit. S/U grading.

C204. Structure, Processing, and Properties of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Discussion of aspects of cement and concrete materials, including manufacture of cement and production of concrete. Aspects of cement composition and basic chemistry, reactions, properties of plastic and hardened concrete, chemical admixtures, and quality control and acceptance testing. Development and testing of fundamentals for complete understanding of cement and concrete engineering materials. By end of term, successful utilization of fundamental materials science concepts to understand, explain, analyze, and describe engineering performance of cement and concrete, concurrently scheduled with course C104. Letter grading. Mr. Sant (W)


206. Modeling and Simulation of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Chemistry 20A, 20B, Mathematics 31A, 31B, 32B, Physics 1A, 1B, 1C. Fundamental examination of modeling and numerical simulations for civil engineering materials, with focus on practical examples and application to students own research. Run simulations at scale relevant to targeted problems. Letter grading.

220. Advanced Soil Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. State of stress, Consolidation and settlement analysis. Shear strength of granular and cohesive soils. In situ and laboratory methods for soil property evaluation. Letter grading. Mr. Stewart (F)


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

223. Slope Stability and Earth Retention Systems. (4) Lecture, two hours; outside study, six hours. Requisites: courses 120, 121, 220. Basic concepts of stability of earth slopes, including shear strength, design charts, limit equilibrium analysis, seepage analysis, drained and undrained conditions. Theory of earth pressures behind retaining structures, with special application to design of retaining walls, sheet piles, mechanically stabilized earth, soil nails, and anchored and braced excavation. Letter grading. Mr. Brandenberg (W)

224. Advanced Cyclic and Monotonic Soil Behavior. (4) Lecture, four hours; outside study, eight hours. Requisites: course 220. In-depth study of soil behavior under cyclic and monotonic loads. Relationships between stress, strain, pore water pressure, and cyclic plasticity in natural and large strain. Concept of normalized static and cyclic soil behavior. Cyclic degradation and liquefaction of saturated soils. Cyclic settlement of partially saturated soils. Concept of volumetric cyclic threshold shear strain. Factors affecting shear moduli and damping during cyclic loading. Postcyclic behavior under monotonic loads. Critical review of laboratory, field, and modeling testing techniques. Letter grading. Mr. Sant (W)

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 clays, seismic compression, surface fault rupture, and seismic slope stability. 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, geosynthetics, solid waste landfills, subsurface barrier walls, and disposal of high water content materials. Letter grading. Mr. Stewart (Sp)

227. Numerical Methods in Geotechnical Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 220. Introduction to basic concepts of computer modeling of soils using finite element method, and to constitutive modeling based on soil behavior as a non-linear constitutive model. Emphasis on numerical applications and identification of modeling concerns such as instability, bifurcation, nonexistence, and nonuniqueness of solutions. Letter grading. Mr. Stewart (Not offered 2018–19)

229. Engineering Geology: Geologic Principles for Engineers. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Engineering geology involves interpretation, evaluation, analysis, and application of geologic information and data to civil works. Topics include geologic characterization and classification of soil and rock units. Relationships developed between landforms, active, past, and ancient geologic processes, ground and surface water, and potential natural hazards. Changes in climate, slope formation, fluvial (river) dynamics, coastal dynamics, and deep-seated processes such as volcanicism, seismicity, and tectonics. Evaluation and analysis of effects of geologic processes to predict their potential effect on land use, development, public health, and public safety. Letter grading. Mr. Stewart (F)

M230A. Linear Elasticity. (4) Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: Mechanical and Aerospace Engineering 156A or 166A. Linear Elasticity. Cartesian tensors, normal strain tensor; Cauchy stress tensor; strain energy; equilibrium equations; linear constitutive relations; plane elastic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading. Mr. Ju, Mr. Mal W

M230B. Nonlinear Elasticity. (4) Same as Mechanical and Aerospace Engineering M256B.) Lecture, four hours; outside study, eight hours. Requisite: course M230A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor; nonlinear and linear strain tensors, strain displacement relations; balance equations, Poi-sonne stresses, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity,
hyperelasticity, thermoelasticity, linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (Sp)

M230C. Plasticity. (4) (Same as Mechanical and Aerospace Engineering M256C.) Lecture; four hours; outside study, eight hours. Requisites: courses M230A, 232. Small and large deformation theories. Letter grading. Mr. Zhang (F)

232. Theory of Plates and Shells. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130. Introduction to basic structural theory; yield functions, flow rules and thermodynamics. Classical rate-dependent viscoplasticity, Perzyna and Duvant/Lions types of viscoplasticity. Thermomechanical aspects. Return mapping algorithms for inelastic finite element implementations. Letter grading. Mr. Ju, Mr. Mal (Sp)


235A. Advanced Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Recommended: courses 135B, 230A. Introduction to 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. Classical and computational elasticity, analysis of laminated anisotropic plates and shells based on classical and first-order shear deformation theories. Elastic-dynamic behavior of laminated plates and cylinders. Letter grading. Mr. Terciroglu (Not offered 2018-19)

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Recommended: courses 135B, 230A. Introduction to finite element systems. Grouping of elements; direct energy formulations for deformable systems; solution methods for linear equations; analysis of structural systems with one-dimensional elements; introduction to variational calculus; discrete element displacement, force, and mixed methods for membrane, plate, shell structures; instability effects. Letter grading. Mr. Burton (F)

235C. Nonlinear Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Classification of nonlinear effects; material nonlinearities; conservative, nonconservative material behavior; geometric nonlinearities. Lagrangian formulation of motion. Finite element methods in geometrically nonlinear problems; postbuckling behavior of structures; solution of nonlinear equations; incremental, iterative, programming methods. Letter grading. Mr. Terciroglu (Sp)


M237A. 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. Terciroglu (W)


C239. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 135B. Elementary structural dynamics course for engineering students. Elastic free and forced vibrations of single degree of freedom systems, introduction to response history and response spectrum analysis approaches for single and multiple degree of freedom systems. Axial, bending, and torsional vibration of beams. Concurrently scheduled with course C137. Letter grading. Mr. Terciroglu (F)

241. Advanced Steel Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses C137, 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 braced frames. Composite steel-concrete structures. Letter grading. Mr. Sabol, Mr. Wallace (Sp)

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

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

244. Structural Reliability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to concepts and applications of structural reliability. Topics include computing first- and second-order estimates of probability of failure in engineered systems, computing sensitivities of failure probability to assumed parameter values, measuring relative importance of random variables associated with systems, identifying relative advantages and disadvantages of various analytical reliability methods, using reliability tools to calibrate simplified building codes, and performing reliability calculations related to performance-based engineering. Letter grading. Mr. Burton (W)

245. Earthquake Ground Motion Characterization. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Corequisite: course C137 or 246. Earthquake fundamentals, including plate tectonics, fault types, seismic waves, and magnitude scales. Characterization of earthquake source, including magnitude range and rate of future earthquakes. Ground motion prediction equations and site effects on ground motion. Seismic hazard analysis. Ground motion selection and modification for response history analysis. Letter grading. Mr. Burton (W) and Mr. Bozorgnia (W)

246. Structural Response to Ground Motions. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses C137, 141, 142, 235A. Spectral analysis of ground motions: response, time, and frequency effects of structures to ground motions due to earthquakes. Computational methods to evaluate structural response. Response analysis, including evaluation of contemporary design standards. Limitations due to idealizations. Letter grading. Mr. Terciroglu, Mr. Wallace (W)

247. Earthquake Hazard Mitigation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 130 and M237A or 246. Concepts of seismic response and performance of base isolation, visco-elastic and hysteretic behavior, elas-tomerically bearings under compression and bending, buckling of bearings, sliding bearings, passive energy dissipation devices, requirements for analysis and passive energy dissipation devices, static and dynamic analysis procedures, code provisions and design methods for seismically isolated structures. Letter grading. Mr. Chang (Sp)

250A. Surface Water Hydrology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 150. In-depth study of surface water hydrology, including discussion and inter-relationship of major topics such as rainfall and evapor-ation, 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. Gebremichael (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 atmosphere, surface water, groundwater, and climate. Letter grading. Mr. Yeh (W) and Mr. Yeh (Not offered 2018-19)

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; optimization of water resources projects; and multiobjective planning and conjunctive use of surface water and groundwater. Emphasis on management of water quantity. Letter grading. Mr. Margulis (W) and Mr. Margulis (W)

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 analysis, and application of models for flood forecasting and prediction of streamflows in water resource applications. Letter grading. Mr. Margulis (W) and Mr. Margulis (W)

251B. Contaminant Transport in Groundwater. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250B, 253. Phenomena and mechanisms of hydrodynamic dispersion, mathematical equations of mass transport in porous media, various analytical and numerical solutions, determination of dispersion parameters by laboratory and field experiments, evaluation and remediation of transport in multiphase flow, remediation design, software packages and applications. Letter grading. Mr. Yeh (Not offered 2018-19) and Mr. Yeh (Not offered 2018-19)

251C. Remote Sensing with Hydrologic Applications. (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 parame
251D. Hydrologic Data Assimilation. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 250C. Introduction to basic concepts of classical and modern information theory, with applications to problems of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models of hydrologic systems. Letter grading. Mr. Gebremichael (Sp)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: Engineering 110, one or more courses in mathematical or 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 (Not offered 2018-19)


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

255A. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 155, 254A. Review of momentum, mass, and energy transfer in natural and aquatic systems, with emphasis on exchanges across phase boundaries: sediment/water interface, air/water gas exchange, particle, droplet, and bubble transfer; and air pollution potential: meteorological factors and air pollution processes. Letter grading. Mr. Mohanty (Not offered 2018-19)

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

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

261. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 254A, 255A. Colloidal interactions, colloidal stability, colloidal hydrodynamics, surface chemistry, adsorption of pollutants on colloidal surfaces, transport of colloids in porous media, coagulation, and particle deposition. Consideration of applications to colloidal processes in aquatic environments. Letter grading. Mr. Hoek (Not offered 2018-19)

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

262A. Introduction to Atmospheric Chemistry. (4) Same as Atmospheric and Oceanic Sciences M203A. Lecture, three hours. Requisite for undergraduates: Chemistry 206B. Principles of chemical kinetics, thermodynamics, spectroscopy, and photochemistry; chemical composition and history of Earth’s atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of troposphere and stratosphere, upper atmosphere chemical processes; air pollution; chemistry and climate. S/U or letter grading.

Mr. M262B. Atmospheric Diffusion and Air Pollution. (4) Same as Atmospheric and Oceanic Sciences M224B. Lecture, three hours. Nature and sources of atmospheric pollution; diffusion from point, line, and area sources; pollution dispersion in urban complexes; meteorological factors and potential; meteorological processes; air pollution potential; meteorological processes of air, SAU or letter grading. (Not offered 2018-19)

263A. Physics of Environmental Transport. (4) Lecture, four hours; outside study, eight hours. De-emphasis on mathematical derivations of the conservation equations applied to environmental interfaces between solid, liquid, and gas phases, such as aquatic sediments, porous aggregates, and vegetative canopies. Discussion of theoretical models and experimental observations. Application to important environmental engineering problems. Letter grading. Ms. Jay (Not offered 2018-19)

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 such as water/air exchange, transport in porous media, and transport in aquatic environments. Letter grading. Mr. Jassby (Not offered 2018-19)

266. Environmental Biotechnology. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 153, 254A. Environmental biotechnology—concept and potential, biotechnology of pollutant control, bioremediation, biomass conversion; composting, biogas and bioethanol production. Letter grade or S/U. Mr. 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 contaminant plumes, and understanding experience in modeling using geochemical software packages commonly found in environmental consulting industry to gain better understanding of governing geochemical principals. 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 include acid mine drainage, nutrient 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. Ms. Jay (Not offered 2018-19)

C282. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Correlation, analysis, and metrization of aspects of pavement design, including materials selection and traffic loading and volume. Special attention to aspects of pavement distress/serviceability and factoring of these into metrics of pavement performance. Discussion of potential choices of pavement materials (i.e., asphalt and concrete) and their specific strengths and weaknesses in paving applications. Unification and correlation of different variables that influence pavement performance and highlight their relevance in pavement design. Concurrently scheduled with course C182. Letter grading. Mr. Sant (Not offered 2018-19)

295. Directed Individual or Tutorial Studies. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Petition forms to request enrollment may be obtained from assistant dean, Graduate Students. Supervised independent study for graduate students. Letter grade or S/U. May be repeated for credit. S/U grading. (F, W, Sp)

296. Directed Individual or Tutorial Studies. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Reading and research for MS candidates, including thesis proposal. Letter grade or S/U. May be repeated for credit. S/U grading. (F, W, Sp)

297. Preparation for MS Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate civil engineering students. Reading and preparation for MS comprehensive examination. S/U grading. (Same as Atmospheric and Oceanic Sciences M297B. Preparation for PhD Preliminary Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. Reading and preparation for PhD preliminary examination, including preliminary research on dissertation. S/U grading.

298. Research for and Preparation of MS Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate civil engineering students. Supervised independent research for MS candidates, including thesis prospectus. S/U grading. (Same as Atmospheric and Oceanic Sciences M298. Research for and Preparation of PhD 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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https://www.cs.ucla.edu

Adnan Y. Darwiche, Ph.D., Chair
Richard E. Korf, Ph.D., Vice Chair
Glenn D. Reinman, Ph.D., Vice Chair

Professors

Junghoo (John) Cho, Ph.D.
Jason (Jingsheng) Cong, Ph.D. (Chancellor’s Professor)
Adnan Y. Darwiche, Ph.D.
Joseph J. DiStefano III, Ph.D.
Milos D. Ercegovac, Ph.D.
Elezar Eskin, Ph.D.
Eliezer M. Gafni, Ph.D.
Mario Gerla, Ph.D. (Jonathan B. Postel Professor of Networking)
Eran Halperin, Ph.D.
Richard E. Korf, Ph.D.
Christopher J. Lee, Ph.D.
Songwu Lu, Ph.D.
Todd D. Mилlein, Ph.D.
Stanley J. Osher, Ph.D.
Rafael Ostrovsky, Ph.D.
Jens Palsberg, Ph.D.
Miodrag Potkonjak, Ph.D.
Glenn D. Reinman, Ph.D.
Amir Sahai, Ph.D.
Majid Sarrafzadeh, Ph.D.
Stefano Soatto, Ph.D.
Mani B. Srivastava, Ph.D.
Demetri Terzopoulos, Ph.D. (Chancellor’s Professor)
Mihaiel van der Schaar, Ph.D.
George Varghese, Ph.D. (Chancellor’s Professor)
Wei Wang, Ph.D. (Leonard Kleinrock Term Professor of Computer Science)
Carlo A. Zaniolo, Ph.D. (Norman E. Friedmann Professor of Knowledge Sciences)
Lixia Zhang, Ph.D. (Jonathan B. Postel Professor of Computer Systems)
Song-Chun Zhu, Ph.D.

Professors Emeriti

Algirdas A. Avizienis, Ph.D.
Rajive L. Bagrodia, Ph.D.
Alfonso F. Cardenas, Ph.D.
Jack W. Carlyle, Ph.D.
Wesley W. Chu, Ph.D.
Michael G. Dyer, Ph.D.
Sheila A. Greibach, Ph.D.
Leonard Kleinrock, Ph.D.
Allen Klinger, Ph.D.
Lawrence P. McNamee, Ph.D.
Richard R. Munzt, Ph.D.
D. Stott Parker, Jr., Ph.D.
Judea Pearl, Ph.D. (Chancellor’s Professor Emeritus)
David A. Rennels, Ph.D.
Jacques J. Vidal, Ph.D.

Associate Professors

Miryung Kim, Ph.D.
Raghu Meka, Ph.D.
Alexander Sherstov, Ph.D.
Yuval Tamir, Ph.D.
Guoqing (Harry) Xu, Ph.D.

Assistant Professors

Kai-Wei Chang, Ph.D.
Jason Ernst, Ph.D.
Allyson K. Fletcher, Ph.D.
Cho-Jui Hsieh, Ph.D.
Quanquan Gu, Ph.D.
Ravi Netravali, Ph.D.
Anthony J. Nowatzki, Ph.D.
Sriram Sankaranarayanan, Ph.D.
Fabien Scalzo, Ph.D., in Residence
Yizhou Sun, Ph.D.
Guy Van den Broeck, 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

David E. Heckerman, Ph.D.
Van Jacobson, M.S.
Alan C. Kay, Ph.D.
Peter L. Reiher, Ph.D.

Adjunct Associate Professor

Giovanni Pau, Ph.D.

Adjunct Assistant Professors

Alexander Afanasyev, Ph.D.
Tyson Condie, Ph.D.
Ameet S. Talwalkar, Ph.D.
Ramin Ramezani, Ph.D.
Carey S. Nachenberg, M.S.
Ramin Ramezani, Ph.D.
Ameet S. Talwalkar, Ph.D.

Scope and Objectives

Computer science is concerned with the design, modeling, analysis, and applications of computer 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, 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 through the Computer Science and Engineering major, the Computer Science major, or the Computer Engineering major described below.

In addition, UCLA Samueli 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 Educational 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.

Computer Science Undergraduate Program Educational Objectives

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

Computer Engineering Undergraduate Program Educational Objectives

The undergraduate computer engineering program prepares students to be able to (1) understand fundamental computing concepts and make valuable contributions to the practice of computer engineering; (2) design, analyze, and implement complex computer systems for a variety of application areas and cyberphysical domains; (3) demonstrate the ability to work effectively in a team and communicate their ideas; (4) continue to learn as part of a graduate program or otherwise in the world of constantly evolving technology.

Undergraduate Study

The Computer Science and Engineering, Computer 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. Computer Engineering majors complete a design course in which they integrate their knowledge of the discipline and engage in creative design within realistic and professional constraints. 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.

The Computer Engineering major is a designated capstone major that is jointly administered by the Computer Science and Electrical and Computer Engineering departments. 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. Students identify, formulate, and solve engineering problems and present their projects to the class.

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 and Computer 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.

Learning Outcomes

The Computer Science and Engineering major has the following learning outcomes:

- Application of basic mathematical and scientific concepts that underlie the modern field
- Design of a software or digital hardware system, component, or process to meet desired needs within realistic constraints
- Function productively with others on a team, including those with different specialities within the field
- Identification, formulation, and solution of computer software- and hardware-related engineering problems
- Effective communication

Preparation for the Major

Required: Computer Science 1, 31, 32, 33, 35L, M51A; Electrical and Computer Engineering 3; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.

The Major

Required: Computer Science 111, 118, 131, M151B, M152A, 180, 181, Electrical and Computer Engineering 100, 102, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A; one capstone design course (Computer Science 152B); 4 units of elective courses selected from Electrical and Computer Engineering 101A through M185; 12 units of elective courses selected from Computer Science 111 through CM187; and 12 units of technical breadth courses selected from an approved list available in the Office of Academic and Student Affairs.

Students who want to deepen their knowledge of electrical engineering are encouraged to select that discipline as their technical breadth area.
Credit is not allowed for both Computer Science 170A and Electrical and Computer Engineering 133A unless at least one of them is applied as part of the technical breadth area. Electrical and Computer Engineering 110, 131A, and CM182 may not satisfy elective credit. A petition may be submitted to consider four units of Computer Science 194 or 199 for an elective. Credit is not guaranteed and subject to vice chair review.

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

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

**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.

**Learning Outcomes**

The Computer Science major has the following learning outcomes:

- Application of basic mathematical and scientific concepts that underlie the modern field
- Design of a software or digital hardware system, component, or process to meet desired needs within realistic constraints
- Function productively with others on a team, including those with different specialties within the field
- Identification, formulation, and solution of computer software- and hardware-related engineering problems
- Effective communication

**Preparation for the Major**

**Required:** Computer Science 1, 31, 32, 33, 35L, M51A; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.

**The Major**

**Required:** Computer Science 111, 118, 131, M151B, M152A, 180, 181; one course from Civil and Environmental Engineering 110, Electrical and Computer 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; 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 taken as an elective only if it is not taken as the capstone course. Credit is not allowed for both Computer Science 170A and Electrical and Computer 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. A petition may be submitted to consider four units of Computer Science 194 or 199 for an elective. Credit is not guaranteed and subject to vice chair review.

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

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

**Computer Engineering B.S.**

**Capstone Major**

The undergraduate curriculum provides all computer engineering students with preparation in the mathematical and scientific disciplines that lead to a set of courses that span the fundamentals of the discipline in the major areas of data science and embedded networked systems. These collectively provide an understanding of many inventions of importance to our society, such as the Internet of things, human-cyber-physical systems, mobile/wearable/implantable systems, robotic systems, and more generally smart systems at all scales in diverse spheres. The design of hardware, software, and algorithmic elements of such systems represents an already dominant and rapidly growing part of the computer engineering profession. Students are encouraged to make use of their computer science and electrical and computer engineering electives and a two-quarter capstone design course to pursue deeper knowledge within one of these areas according to their interests, whether for graduate study or preparation for employment.

**Learning Outcomes**

The Computer Engineering major has the following learning outcomes:

- Application of mathematical, scientific, and engineering knowledge
- Design of a software or hardware system, component, or process to meet desired needs within realistic economic, environmental, social, ethical, health, safety, security, reliability, manufacturability, and sustainability constraints
- Function productively on a team with others
- Identification, formulation, and solution of computer engineering problems
- Effective communication

**Preparation for the Major**

**Required:** Computer Science 1 (or Electrical and Computer Engineering 1), 31, 32, 33, 35L, M51A (or Electrical and Computer Engineering M16); Electrical and Computer Engineering 3; Engineering 96C; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.

**The Major**

**Required:** Computer Science 111, 118 (or Electrical and Computer Engineering 132B), M151B (or Electrical and Computer Engineering M116C), M152A (or Electrical and Computer Engineering M116L), 180; Electrical and Computer Engineering 100, 102, 113, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, Statistics 100A; 8 units of computer science and 8 units of electrical and computer engineering upper-division electives; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 8 units capstone design from either Electrical
Suggested Tracks

**Networked Embedded Systems:** This track targets two related trends that have been a significant driver of computing, namely stand-alone embedded devices becoming networked and coupled to physical systems, and the Internet evolving toward a network of things (the IoT). These may broadly be classified as cyber physical systems, and includes a broad category of systems such as smart buildings, autonomous vehicles, and robots, which interact with each other and other systems. This trend in turn is driving innovation both in the network technologies (new low-power wireless networks for connecting things, and new high-speed networks and computing infrastructure to accommodate the transport and processing needs of the deluge of data resulting from continual sensing), and in embedded computing (new hardware and software stack catering to requirements such as ultra-low power operation, and embedded machine learning).

Students pursuing this track are strongly encouraged to take Electrical and Computer Engineering M119 or Computer Science M119 in junior year, and to choose three electives from courses such as Computer Science 117, 130, 131, 132, 133, 136, 181, 188, Electrical and Computer Engineering 2, 115A, 115B, 115C, 132A, 133A, 141, 142, 188.

Students who pursue a technical breadth area in either electrical and computer engineering or computer science can choose an additional three courses from this list.

**Data Science:** This track targets the trend toward the disruptive impact on computing systems, both at the edge and in the cloud, of massive amounts of sensory data being collected, shared, processed, and used for decision making and control. Application domains such as health, transportation, energy, etc. are being transformed by the abilities of inference-making and decision-making from sensory data that is pervasive, continual, and rich. This track will expose students to the entire data-to-decision pathway spanning the entire stack from hardware and software to algorithms, applications, and user experience.

Students pursuing this track are strongly advised to take Computer Science 143 and M146 or Electrical and Computer Engineering M146, and to additionally choose two electives from courses such as Computer Science CM121, 136, 144, 145, 161, 188, Electrical and Computer Engineering 114, 133A, 133B, 134, 188.

Students who pursue a technical breadth area in either electrical and computer engineering or computer science can choose an additional three courses from this list.

Students are also free to design ad hoc tracks. The technical breadth area requirement provides an opportunity to combine elective courses in electrical and computer engineering and computer science with those from another UCLA Samueli major to produce a specialization in an interdisciplinary domain. As noted above, students can also select a technical breadth area in either Electrical and Computer Engineering or Computer Science to deepen their knowledge in either discipline.

**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 or 7A, 23L, Mathematics 33A

**Required Upper-Division Courses (18 units minimum):**
- Computer Science 180 (or Mathematics 182), M184, two courses selected from Computer Science CM121, CM122, and CM124, and one course selected from Chemistry and Biochemistry C100, 135B, Civil and Environmental Engineering 110, Computer Science CM121, CM122, CM124, 170A, CM186, CM187, Ecology and Evolutionary Biology C135, Electrical and Computer Engineering 102, 131A, 141, Human Genetics C144, Mathematics 170A, Microbiology, Immunology, and Molecular Genetics 132, Molecular, Cell, and Developmental Biology 144, 187AL, 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.

If students apply any of Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A toward major requirements or another minor, then no other course from that set may be applied toward the minor requirements.

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

All minor courses must be taken for a letter grade (unless not offered on that grading basis), and students must have a minimum grade of C– in each and an overall C (2.0) grade-point average in all courses taken for the minor. Successful completion of the minor is indicated on the transcript and diploma.

**Graduate Study**

For information on graduate admission, see Graduate Programs on page 25.

The following introductory information is based on 2018-19 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. 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 Computer Science offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Computer Science and participates in a concurrent degree program (Computer Science M.S./Management M.B.A.) with the John E. Anderson Graduate School of Management.
Computer Science M.S.

Course Requirements

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

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, 199, Electrical and Computer Engineering 100, 101A, 102, 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 MS degree, students must also complete at least three terms of Computer Science 201 with grades of Satisfactory.

Competence in any or all courses in breadth requirements may be demonstrated in one of three ways:

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

Comprehensive Examination Plan

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

Thesis Plan

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

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

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

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

Computer Science Ph.D.

Major Fields or Subdisciplines

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

Course Requirements

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

The fundamental examination is common for all Ph.D. candidates in the department and is also known as the written qualifying examination.

To satisfy the major field requirement, students are expected to attain a body of knowledge contained in five courses, as well as the current literature in the area of specialization. In particular, students are required to take a minimum of three 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 two courses, at least one of which is a graduate course. Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, are required. By petition and administrative approval, a minor field may be satisfied by examination.

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

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

Competence in any or all courses may be demonstrated in one of three ways:

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

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

Computational Systems Biology
The computational systems biology (CSB) field can be selected as a major or minor field for the Ph.D. or as a specialization area for the M.S. degree in Computer Science. Graduate studies and research in the CSB field are focused on computational modeling and analysis of biological systems and biological data.
Core coursework is concerned with the methods and tools development for computational, algorithmic, and dynamic systems network modeling of biological systems at molecular, cellular, organ, whole organism, or population levels—and leveraging them in biosystem and bioinformatics applications. Methodological studies include bioinformatics and systems biology modeling, with focus on genomics, proteomics, metabolomics, and higher levels of biological/physiological organization, as well as multiscale approaches integrating the parts.
Typical research areas with a systems focus include molecular and cellular systems biology, organ systems physiology, medical pharmacological, pharmacokinetic (PK), pharmacodynamic (PD), toxicokinetic (TK), physiologically based PBPK-PD, PBTK, and pharmacogenomic system studies; neurosystems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. Typical research areas with a bioinformatics focus include development of computational methods for analysis of high-throughput molecular data, including genomic sequences, gene expression data, protein-protein interaction, and genetic variation. These computational methods leverage techniques from both statistics and algorithms.

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

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

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

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

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

The term theoretical computer science has come to be applied nationally and intentionally to a certain body of knowledge emphasizing the interweaving themes of computability and algorithms, interpreted in the broadest sense. Under computability, one includes questions concerning which tasks can and cannot be performed by information systems of different types restricted in various ways, as well as the mathematical analysis of such systems, their computations, and the languages for communication with them. Under algorithms, one includes questions concerning (1) how a task can be performed efficiently under reasonable assumptions on available resources (e.g., time, storage, type of processor), (2) how efficiently a proposed system performs a task in terms of resources used, and (3) the limits on how efficiently a task can be performed. These questions are often addressed by first developing models of the relevant parts of an information processing system (e.g., the processors, their interconnections, 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.

<table>
<thead>
<tr>
<th>Emphasis of Computer Science Theory</th>
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<tr>
<td>• Design and analysis of algorithms</td>
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<tr>
<td>• Distributed and parallel algorithms</td>
</tr>
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<td>• Models for parallel and concurrent computation</td>
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<td>• Online and randomized algorithms</td>
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<tr>
<td>• Computational complexity</td>
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<td>• Automata and formal languages</td>
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<td>• Cryptography and interactive proofs</td>
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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 from single-chip to computing clouds.

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 used in a wide range of computing devices from smartphones to data centers.

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

3. The study of computational algorithms and structures deals with the relationship between computational algorithms and the physical structures that can be employed to carry them out. It includes the study of interconnection networks, and the way that algorithms can be for-
Systems are based on the coordination mechanisms, explanation facilities, and support and query and includes inference rules and trees. In addition, information management has become essential. The need for sophisticated information and data generalization of data management in which 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.

**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 application 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.

**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
http://reasoning.cs.ucla.edu

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.

**Cognitive Systems Laboratory**

Judea Pearl, Director
http://singapore.cs.ucla.edu/cogsys.html

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.; graphical, 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.

**Computational Systems Biology Laboratories**

Biocytbernetics Laboratory
Joseph J. DiStefano III, Director
http://biocyb.cs.ucla.edu/research.html

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).

**Computational Genetics Laboratory**

Eleazar Eskin, Director
http://zarlab.cs.ucla.edu/about/

The laboratory is comprised of a computational genetics group affiliated with both the Computer Science and Human Genetics departments. Research interests are in com-
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.

**Computer Systems Architecture Laboratories**

**Concurrent Systems Laboratory**

Yuval Tamir, Director  
http://web.cs.ucla.edu/csd/research/labs/csl/

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.

**Digital Arithmetic and Reconfigurable Architecture Laboratory**

Milos D. Ercegovac, Director  
http://arithmetic.cs.ucla.edu

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.

**eHealth Research Laboratory (ER Lab)**

Majid Sarrafzadeh, Director  
http://er.cs.ucla.edu

The ER Lab goal is to use technology in health care to reduce the cost of providing high-quality care to the chronically ill, estimated (by Milken Institute Center for Health Care Economics) to be over $1 trillion per year. The laboratory strives to improve global and local public health surveillance, with a resultant reduction in epidemics, increased control over infectious disease, and improved drug safety. Other goals are diminished rate of medical errors; ongoing preventive health, with attendant reductions in morbidity, mortality, and cost of care; and consumer engagement in health and self-management.

**VAST Laboratory**

Jason Cong, Director  
http://vast.cs.ucla.edu

The VAST 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.

**Graphics and Vision Laboratories**

**Center for Vision, Cognition, Learning, and Art**

Song-Chun Zhu, Director  
http://vcla.stat.ucla.edu

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 unified frameworks 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.).

**Computer Graphics and Vision Laboratory (MAGIX)**

Demetri Terzopoulos, Director  
http://www.cs.ucla.edu/magix

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.

**UCLA Collective on Vision and Image Sciences**

http://visciences.ucla.edu

The Collective brings together researchers from multiple departments at UCLA, including Mathematics, Statistics, Computer Science, Brain Mapping, Computational Biology, Neuro Imaging, Image Informatics, Psychology, and Radiology.

**UCLA Vision Laboratory**

Stefano Soatto, Director  
http://vision.ucla.edu

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.

**Information and Data Management Laboratories**

**Information and Data Management Group**

(Multiple Faculty)  
http://www.cs.ucla.edu/idm/

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.

**Web Information Systems Laboratory**

Carlo A. Zaniolo, Director  
http://wis.cs.ucla.edu/wis/

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 datalog system; SemScape, an NLP-based framework for mining unstructured or free text; EARL (Early Accurate Result Library) for Hadoop; Panta Rei, a study of support for schema evolution in the context of snapshot databases and transaction-time databases; Stream Mill, a complete data stream management system; and ArchiS, a powerful archival information system.

**Network Systems Laboratories**

**Internet Research Laboratory (IRL)**

Lixia Zhang, Principal Investigator  
http://irl.cs.ucla.edu

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.
Laboratory for Advanced System Research (LASR)
Peter L. Reiher, Principal Investigator
http://www.lasr.cs.ucla.edu
The laboratory engages in research to develop advanced operating systems, distributed systems, middleware, and security systems.

Network Research Laboratory
Mario Gerla, Director
http://nrl.cs.ucla.edu
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.

Wireless Networking Group (WiNG)
Songwu Lu, Director
http://metro.cs.ucla.edu
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.

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

Software Systems Group
(Multiple Faculty)
http://software.cs.ucla.edu
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.

Computer Science Centers
Center for Autonomous Intelligent Networked Systems (CAINS)
http://www.cains.cs.ucla.edu
The center was established in 2001 with researchers from several laboratories in the Computer Science and Electrical and Computer 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.

Center for Domain-Specific Computing (CDSC)
http://www.cdsc.ucla.edu
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 health care 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 and Computer 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.

Center for Information and Computation Security (CICS)
http://www.cs.ucla.edu/security/
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 received federal, state, and private-sector funding, including collaboration with Israel through multiple U.S.–Israel Binational 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.

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.

Wireless Health Institute (WHI)
Benjamin M. Wu, D.D.S., Ph.D. (Bioengineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), 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.

WHI technology always serves the clinician community through joint development of innovations and clinical trial validation. Each WHI program is focused on large-scale product delivery in cooperation with manufacturing partners. WHI collaborators include 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 technologies 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.

Computing Resources

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

Hardware

Computing facilities range from large campus-operated supercomputers to a major local network of servers and workstations that are administered by the department computing facilities (DCF) or school network (SEASnet).

The departmental research network includes Oracle servers and shared workstations, on the school 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 Information 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

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

Database, web technologies, information discovery and integration

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 nanotechnologies

Adrian Y. Darviche, 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

Mitos 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

Eliezer M. Gafni, Ph.D. (MIT, 1982)

Computer communication, networks, mathematical programming algorithms

Mario Gerla, Ph.D. (UCLA, 1973)

Wireless ad hoc networks; MAC, routing and transport protocols, vehicular communications, peer-to-peer mobile networks, personal-area networks (Bluetooth and Zigbee), underwater sensor networks, Internet transport protocols (TCP streaming), Internet path characterization, capacity and bandwidth estimates, analytic and simulation models for network and protocol performance evaluation

Eran Halperin, Ph.D. (Tel Aviv U., Israel, 2000)

Computational biology, population genetics, statistical genetics and epigenetics, machine learning, algorithms


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, 1999)

Integrated-service bandwidth estimation for heterogeneous networks, e.g., mobile computing environments, Internet and ActiveNet: networking and computing, wireless communications and networks, computer communication networks, dynamic game theory, dynamic systems, neural networks, and information economics


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


Scientific computing and applied mathematics

† Rafail Ostrovsky, Ph.D. (MIT, 1992)

Theoretical computer science algorithms, cryptography, complexity theory, randomized network protocols, geometric algorithms, data mining

Jens Palsberg, Ph.D. (Aarhus U., Denmark, 1992)

Compilers, embedded systems, programming languages

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 computing and communications

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

Microprocessor architecture, exploitation of instruction/thread/memory-level parallelism, power-efficient design, hardware/software co-design, reconfigurable computing, design for nanotechnologies

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

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

Energy aware networking and computing, embedded networking and computing, wireless systems and applications, and embedded technology

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

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

Mhiela 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

George Varghese, Ph.D. (MIT, 1993)

Computer networks

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

Data mining, bioinformatics and computational biology, databases

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

Knowledge bases and deductive databases, parallel execution of PROLOG programs, formal

* Also Professor of Medicine

† Also Professor of Mathematics
software specifications, distributed systems, big data, artificial intelligence, and computational biology.

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

Computer network, Internet architecture, protocol design, 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

**Professors Emeriti**

Algidas A. Avizienis, Ph.D. (U. Illinois, 1960)

Digital computer architecture and design, fault-tolerant computing, digital arithmetic

Rajeev L. Bagrodia, Ph.D. (U. Texas, 1987)

Wireless networks, nomadic computing, parallel programming, evaluation of computer and communication systems

Alfonso F. Cardenas, Ph.D. (UCLA, 1969)

Distributed file systems, distributed database systems, reconfigurable computing, parallel and distributed computing systems

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

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

Sheila A. Greibach, Ph.D. (Harvard, 1963)

Theoretical computer science, computational complexity, program schemes and semantics, formal languages, automata, computability

Leonard Kleinrock, Ph.D. (MIT, 1963)

Computer networks, computer-comms systems, resource sharing and allocation, computer systems modeling analysis and design, queueing systems theory and applications, performance evaluation of congestion-prone systems, performance evaluation and design of distributed multiaccess packet-switching systems, wireless networks, mobile computing, nomadic computing, and distributed and parallel processing systems

Allen Klinger, Ph.D. (UC Berkeley, 1966)

Pattern recognition, picture processing, biomedical applications, mathematical modeling

Lawrence P. McNamee, Ph.D. (U. Pittsburgh, 1964)

Computer networking, computer simulations, digital filtering, computer-aided design, LSI fabrication techniques, printed circuit board design


Multimedia systems, database systems, data mining

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

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

Judea Pearl, Ph.D. (Polytechnic Institute of Brooklyn, 1965)

Artificial intelligence, philosophy of science, reasoning under uncertainty, causal inference, causal and counterfactual analysis

David A. Rennels, Ph.D. (UCLA, 1973)

Digital computer architecture and 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**

Myung Kim, Ph.D. (U. Washington, 2008)

Software engineering specifically on software evolution

Raghup Meka, Ph.D. (U. Texas Austin, 2011)

Complexity theory, pseudorandomness, algorithms, learning probability and data mining

Alexander Sherstov, Ph.D. (U. Texas Austin, 2009)

Complexity theory with a focus on communication and circuit complexity, computational learning theory, quantum computing

Yuval Tamar, Ph.D. (UCL Berkeley, 1985)

Computer systems, computer architecture, software systems, parallel and distributed systems, dependable systems, cluster computing, reliable network services, interconnection networks and switches, multi-core architectures, reconfigurable computing

Guoqing (Harry) Xu (Ohio State, 2011)

Programming languages, compilers, runtime systems, distributed systems, big data systems and analytics, software engineering

**Assistant Professors**

Kai-Wei Chang, Ph.D. (U. Illinois Urbana-Champaign, 2015)

Tractable machine learning methods for complex and big data, statistical approaches to natural language processing

Jason Ernst, Ph.D. (UCLA, 2008)

Computational biology, bioinformatics, machine learning and analytics

Alyson K. Fletcher, Ph.D. (UCL Berkeley, 2006)

Applied mathematics including inverse problems, statistical physics, dynamical systems, machine learning, information theory

Quanquan Gu, Ph.D. (U. Illinois Urbana-Champaign, 2014)

Machining learning, high-dimensional statistical inference, optimization, data mining

Cho-Jui Hsieh, Ph.D. (U. Texas Austin, 2015)

Fast and scalable algorithms for large-scale machine learning (deep learning), fast prediction and model compression for big ML models, low-rank models for recommender systems, theoretical analysis of optimization algorithms, security for machine learning

Ravi Netrapalli, Ph.D. (MIT, 2018)

Computer systems, computer networks, distributed systems, cloud computing


Hardware/software co-design, modeling, and optimization

Sriram Sankaraman, Ph.D. (UCL Berkeley, 2010)

Computational biology, computational/statistical genomics, statistical machine learning probabilistic graphical models, Bayesian statistics

Fabien Scalzo, Ph.D. (U. Liège, Belgium, 2008)

Stroke and traumatic brain injuries (TBI) using brain mapping of imaging and biosignals (MR, DT, X-ray angiography), TCD, and ICP; development of machine learning and computer vision algorithms to improve neurocritical care and bring understanding of neurological disorders

Yizhou Sun, Ph.D. (U. Illinois Urbana-Champaign, 2012)

Information and social network analysis, data mining, database systems, statistics, information retrieval, machine learning and network science

**Member of Brain Research Institute**

Guy Van den Broeck, Ph.D. (Katholieke U. Leuven, Belgium, 2013)

Machine learning (statistical relational learning), knowledge representation and reasoning (graphical models, lifted probabilistic inference), applications of probabilistic reasoning and learning (probabilistic programming, probabilistic databases), artificial intelligence

**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**

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 (NDN), content-centric networking

Amit Kar, Ph.D. (U. Utah, 1969)

Object-oriented programming, personal computing, graphical user interfaces

Peter L. Reiher, Ph.D. (UCLA, 1987)

Computer and network security, ubiquitous computing, file systems, distributed systems

**Adjunct Associate Professor**

Giovanni Pau, Ph.D. (U. Bologna, Italy, 1998)

Protocol design implementation and evaluation for QOS support in wired/wireless networks and vertical handover protocols and architectures

**Adjunct Assistant Professors**

Alexander Atanasiev, Ph.D. (UCLA, 2013)

Named data networking (NDN), information-centric networking (ICN)

Tyson Condie, Ph.D. (UCL Berkeley, 2010)

Large-scale distributed data management, declarative languages, systems for machine learning and big data analysis

Carey S. Nachenberg, M.S. (UCLA, 1995)

Anti-virus and intrusion detection technology


Logic and AI, inductive logic programming, constraint solving, machine learning, combined reasoning, signal processing

Ameet S. Talwalkar, Ph.D. (New York U., 2010)

Statistical machine learning, scalable data analytics, computational genomics

**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 twelve 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. Assignments given to bolster independent study and writing skills. Letter grading.

Mr. Darwinche (F)

19. Fiat Lux Freshman Seminars. (1) Seminar, one hour. Discussion of and critical thinking about topics of current, 1 hour discussion, 2 hour taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

30. Principles and Practices of Computing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for students in computer science and related majors who do not have prior programming experience. Precursor course to introductory computer science sequence (courses 31, 32, 33). Teaches students how to use computers as tool for problem solving, creativity, and exploration through design and implementation of computer programs. Key topics are data types including integers, strings, and lists; control structures, including conditionals and loops; and functional decomposition. Letter grading.

Mr. Millstein (F)

31. Introduction to Computer Science I. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for students in computer science and related majors who have not prior programming experience. Precursor course to introductory computer science sequence (courses 31, 32, 33). Teaches students how to use computers as a tool for problem solving, creativity, and exploration through design and implementation of computer programs. Key topics are data types, including integers, strings, and lists; control structures, including conditionals and loops; and functional decomposition. Letter grading.

Mr. Palsenberg, Mr. Smallberg (F,W,Sp)

32. Introduction to Computer Science II. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for students in computer science and related majors who have not prior programming experience. Precursor course to introductory computer science sequence (courses 31, 32, 33). Teaches students how to use computers as a tool for problem solving, creativity, and exploration through design and implementation of computer programs. Key topics are data types, including integers, strings, and lists; control structures, including conditionals and loops; and functional decomposition. Letter grading.

Mr. Palsenberg, Mr. Smallberg (F,W,Sp)

33. Introduction to Computer Organization. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for students in computer science and related majors who have not prior programming experience. Precursor course to introductory computer science sequence (courses 31, 32, 33). Teaches students how to use computers as a tool for problem solving, creativity, and exploration through design and implementation of computer programs. Key topics are data types, including integers, strings, and lists; control structures, including conditionals and loops; and functional decomposition. Letter grading.

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

35L. Software Construction Laboratory. (3) Laboratory, four hours; outside study, five hours. Requirements: Object-oriented software tools and environments, particularly open-source tools to be used in upper-division computer science courses. Letter grading.

Mr. Eegert (F,W,Sp)

M51A. Logic Design of Digital Systems. (4) (Same as Electrical and Computer Engineering M161.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems: data and control selection. Number system and arithmetic, error control codes for digital information. Letter grading.

Mr. Mr. Kofo (F,W,Sp)

97. Variable Topics in Computer Science. (1 to 2) Tutorial, one to four hours; discussion, zero to two hours. Designed for students in computer science and related majors who have not prior programming experience. Precursor course to introductory computer science sequence (courses 31, 32, 33). Teaches students how to use computers as a tool for problem solving, creativity, and exploration through design and implementation of computer programs. Key topics are data types, including integers, strings, and lists; control structures, including conditionals and loops; and functional decomposition. Letter grading.

Mr. Ercogec, Mr. Potkonjak (F,W,Sp)

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

Mr. Korf (F,W,Sp)

Upper-Division Courses


Mr. Kampe, Mr. Reher (F,W,Sp)

112. Modeling Uncertainty in Information Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 111 and one course from Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 10A. Designed for juniors/seniors. Probability and stochastic process models as applied in computer science. Basic methodological tools include random variables, conditional probability, expectation and variance, moment generating, Markov chains. Applications include probabilistic algorithms, evidential reasoning, analysis of algorithms and data structures, reliability, communication protocol and queuing models. Letter grading.

Mr. Sanadidi, Mr. Soatto (Not offered 2018-19)

117. Computer Networks: Physical Layer. (4) Formerly numbered 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, with focus on wireless communication technologies and mobile network and mobile ad hoc networks. Systems include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio networking and computing (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. Dzhafarov (F)

118. Computer Network Fundamentals. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: 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 wirelesss channels. Letter grading.

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

M119. Fundamentals of Embedded Networked Systems. (4) (Same as Electrical and Computer Engineering M119.) Lecture, four hours; discussion, one hour. Enforced requisites: courses 31, 32, 33. Fundamentals of design and principles of operation of cyber physical systems such as devices and systems constituting Internet of Things. Topics include signal propagation and modulation, sensor, actuator and controller design, and applications. Letter grading.

Mr. Srivastava (Sp)

CM121. Introduction to Bioinformatics. (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Requirements: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, 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 methodologies, with emphasis on concepts and inventing new computational and statistical approaches to analyze biological data. Focus on sequence analysis and alignment algorithms. Concurrently scheduled with course CM221. P/NP or letter grading.

Mr. Lee (Not offered 2018-19)

CM122. Algorithms in Bioinformatics. (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Requirements: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Course CM121 is not prerequisite to CM122. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and solving these problems using algorithmic techniques. Computational technologies include those from statistics and computer science. Concurrently scheduled with course CM222. Letter grading.

Mr. Eski (W)

CM124. Computational Genetics. (4) (Same as Human Genetics CM124.) Lecture, four hours; discussion, two hours; outside study, six hours. Requirements: course 32 or Program in Computing 10C with grade of C– or better, Mathematics 33A, and one course from Civil Engineering 110, Electrical Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for engineering students as well as students from biological sciences and medical school. Introduction to computational analysis of genetic variation and computational interdisciplinary research in genetics. Topics include introduction to genetics, identification of genes involved in disease, inferring human population histories, technologies for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and solving these problems using algorithmic techniques. Computational technologies include those from statistics and computer science. Currently scheduled with course CM224. Letter grading.

Mr. Halperin, Mr. Sankararaman (Sp)

130. Software Engineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requirements: courses 111, 131. Recommended requisites: Engineering 183EW or 185EW. Structured programming, program specification, program proving, modularity, abstract data type design, software tools, software control systems, program testing, team programming. Letter grading.

Mr. Eggert, Ms. Kim (W,Sp)

131. Programming Languages. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requirements: courses 33, 35L. Basic concepts in design and use of programming languages, including abstraction, modularity, control mechanisms, and...
types, declarations, syntax, and semantics. Study of several different paradigms, including procedural, functional, object-oriented, and logic programming. Letter grading. Mr. Egert, Mr. Millstein (F,Sp)

132. Compiler Construction. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 111 (may be taken concurrently), 131. Distributed memory and shared memory parallel architectures; asynchronous parallel language and primitive; parallel computation; specification of parallelism, interprocess communication and synchronization; design of parallel programs for scientific computation and distributed systems. Letter grading. Mr. Cong (W)

136. Introduction to Computer Security. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 118. Introduction to basic concepts of information security necessary for software security: risk and threat modeling; cryptographic and network security; secure application design; and ethics and law. Letter grading. Mr. Reihier (F)

C137A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course C131. Study of various programming languages to shed light on design and structural properties of each language 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 C237A. Letter grading. Mr. Millstein (Not offered 2018-19)

C137B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisite: course C137A. Study of various programming language designs, from computing history and research literature, that attempt to address problems of software complexity that are bloated, buggy, and difficult to maintain and extend despite trend in computing toward ever higher levels of abstraction for programming. Hands-on experience designing, prototyping, and evaluating new languages, language abstractions, and/or programming environments. Concurrently scheduled with course C237B. Letter grading. Mr. Millstein (Not offered 2018-19)


144. Web Applications. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 143. Important concepts and theory for building effective and safe Web applications. First-hand experience with Web topics. Topics include basic Web architecture and protocol, XML and XML query language, mapping between XML and relational models, information retrieval model and theory, security and user modes, Web services and distributed transactions. Letter grading. Mr. Cho (F)

145. Introduction to Data Mining. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 180. Introductory survey of data mining (process of automatic discovery of patterns, changes, associations, and anomalies in data) knowledge engineering, and wide spectrum of data mining application areas such as bioinformatics, e-commerce, environmental studies, financial markets, multimedia data processing, network monitoring, and social analysis. Letter grading. Ms. Sun (FW)

M146. Introduction to Machine Learning. (4) (Same as Electrical and Computer Engineering M146.) Lecture, four hours; discussion, one hour; outside study, six hours. Enforced requisite: courses 113 and Environmental Engineering 110 or Electrical and Computer Engineering 131A or Mathematics 170A or Statistics 100A. 23, Introduction to breadth of data science—foundational data sources, principles of operation of common tools for data analysis, and application of tools and models to data gathering and analysis. Topics include statistical foundations, regression, classification, kernels, methods, clustering, data visualization, principal component analysis, decision theory, reinforcement learning and deep learning. Letter grading. Mr. Chang, Mr. Sankaranarayanan (FW)

M151B. Computer Graphics Laboratory. (2) (Same as Electrical and Computer Engineering M116C.) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 33, and M51A or Electrical and Computer Engineering M166. Recommended: courses 111, and M152A or Electrical and Computer Engineering M116L. Computer system organization and design, implementation of CPU datapath and control, construction of display devices, hardware interface design, and computer graphics applications. Letter grading. Mr. Reinman, Mr. Tamir (FW)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical and Computer Engineering M116L) Laboratory, four hours; outside study, two hours; laboratory, four hours. Enforced requisite: course M51A or Electrical and Computer Engineering M16. Hands-on design implementation and debugging of digital logic circuits, use of computer-aided design tools for schematic capture shape and appearance of real objects and scenes. Including angiography, computed tomography (CT), and magnetic resonance (MR). Project-based course covers fundamental topics in data image processing, atlasing, predictive modeling, personalized medicine, data driven and machine learning methods. Letter grading. Mr. Scalo (Sp)

170A. Mathematical Modeling and Methods for Computer Science. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 180, Mathematics 33B. Introduction to methods for modeling and simulation using interactive computing environments for the cov-
Ment (reverse engineering and postprocessing of movies, game design, computer graphics), which includes the study of shapes (curves and characters) to medicine (modeling of biological structures from imaging data), mixed reality (augmentation of video), and security (visual surveillance). Fundamental topics include the modeling and inference of geometric (shape) and photometric (reflectance, illumination) properties of objects and scenes, and for rendering and manipulating novel views. Letter grading. Mr. Soatto (Not offered 2018-19)

C174C. Computer Animation. (4) Lecture, four hours; discussion; two hours; outside study; six hours. Enforced requisites: course 174A. Designed for juniors/seniors. Introduction to computer animation, including 3D model creation, animation techniques, lighting, rendering, and inverse kinematics, forward and inverse dynamics, motion capture animation techniques, physics-based animation of particles and systems, and motion control. Corequisite scheduled with course C274C. Letter grading. Mr. Terzopoulos (Not offered 2018-19)

180. Introduction to Algorithms and Complexity. (4) Lecture, four hours; discussion, two hours; outside study; six hours. Enforced requisites: course 32, Mathematics 61. Designed for junior/senior Computer Science majors. Introduction to design and analysis of algorithms. Design techniques: divide-and-conquer, greedy, dynamic programming; selection of prototypical algorithms; choice of data structures and representations; complexity measures: time, space, upper, lower bounds, asymptotic complexity and complexity classes. Letter grading. Mr. Gafni, Mr. Ostrovsky, Mr. Saratrazadeh (F,W,Sp)

181. Introduction to Formal Languages and Automata Theory. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 180. Designed for junior/senior Computer Science majors. Grammars, automata, and languages. Finite-state languages and finite-state automata. Context-free languages and pushdown automata. Unrestricted rewriting systems, recursively enumerable and recursive languages, and Turing machines. Closure properties, pumping lemmas, and decidability. Introduction to computability. Letter grading. Mr. Sahai, Mr. Sherstov (F,W,Sp)

M182. Systems Biomedicine and Simulation Basics. (4) (Same as Bioengineering M182B.) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Requisite: Mathematics 32B or Life Sciences 30B. Recommended corequisite: Mathematics 3C, 32A, or Life Sciences 30B. Designed for undergraduate students in life sciences and engineering. Introduction to explicit modeling and simulation of dynamic biological systems. Presentation of how biology, biochemistry, and physiology underlying dynamic systems biomodeling are transformed into system diagrams and graphs for refining conceptual understanding of their form and function. Structural models, formulated from basic conservation and mass action laws and feedback concepts, are further transformed into first-order differential equations, and implemented in simulation diagrams for quantifying and exploring biological system properties. Examples show how to use these explicit models to gain clarity on nature of biostystem phenomena, and frame questions and explore new ideas for research. Letter grading. Mr. DiStefano (F,W,Sp)

183. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory, enforced requisites: course 180. Introduction to cryptography, computer security, and basic concepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public-key and private-key encryption, key-agreement, homomorphic encryption, private information retrieval and voting protocols, message authentication, and interactive proof systems. Letter grading. Mr. DiStefano (W)

185. Research Opportunities in Computational and Systems Biology. (4) (Same as Computational and Systems Biology M185.) Lecture, two hours; outside study, four hours. Enforced requisites: one course from 31, Civil Engineering M20, Mechanical and Aerospace Engineering M20, or Program in Computer Engineering M10, and Mathematics 3B or 31B. Survey course designed to introduce students to computational and systems modeling and computation in biology and medicine, providing motivation, flavor, culture, and cutting-edge contributions in computational and systems biology, 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. DiStefano, Mr. Eskin (F)

M185. Research Opportunities in Computational and Systems Biology. (4) (Same as Computational and Systems Biology M185.) Lecture, two hours; discussion, two hours; outside study, six hours. Requisite: course 180. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field or of research of faculty mentor or students. May be repeated for credit. Letter grading. (F,W,Sp)

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

Graduate Courses

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


203. Cross-Departmental Seminar. (1) Lecture, to be arranged. Limited to upperclassmen. Studies cross-disciplinary topics of current or historical scientific importance. Letter grading. May be repeated for credit. (F,W,Sp)

204. Seminar in Computer Science. (1) Lecture, to be arranged. Letter grading. May be repeated for credit. (F,W,Sp)

205. Health Analytics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 31, 180. Recommended: statistics and probability, numerical methods, knowledge in programming languages. Applied data analytics course, with focus on healthcare applications. How to properly generate and analyze health data. Project-based course to learn about best practices in health data collection and validation. Exploration of various machine learning and data analytic tools to learn underlying structure of datasets to solve healthcare problems. Different machine learning concepts and algorithms, statistical models, and building of data-driven models. Big data analytics and tools for handling structured, unstructured, and semistructured data. Letter grading. (F,W,Sp)

211. Network Protocol and Systems Software Design for Wireless and Mobile Internet. (4) Lecture, four hours; outside study, eight hours. Requisite: course 118. Designed for graduate students. In-depth study of network protocol and systems software design in area of wireless and mobile Internet. Topics include (1) networking fundamentals: design philosophy of TCP/IP, end-to-end arguments, and protocol design principles, (2) protocols: 802.11 MAC standard, packet scheduling, mobile IP, ad hoc routing, and wireless TCP, (3) mobile computing systems software: middleware, file system, services, and applications, and (4) topics in modern computer science. (F,W,Sp)


213. Machine Learning. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 180, 205. Designed for graduate students. Machine learning is the study of algorithms to find patterns in data and make predictions in new data. This course will cover the core concepts of modern machine learning, with a focus on supervised learning algorithms, regression, classification, and clustering. Students will learn about fundamental machine learning algorithms and their applications in various domains. Letter grading. (F,W,Sp)

214. Research Group Seminars: Computer Science. (4) Seminar, four hours; outside study, eight hours. Enforced requisites: course 201. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field or of research of faculty mentor or students. May be repeated for credit. Letter grading. (F,W,Sp)

215. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: course 180. Introduction to cryptography, computer security, and basic concepts and techniques. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, semantic security, public-key and private-key encryption, key-agreement, homomorphic encryption, private information retrieval and voting protocols, message authentication, and interactive proof systems. Letter grading. Mr. Gerfa
M213A. Embedded Systems. (4) Same as Electrical and Computer Engineering M202B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for graduate computer science and electrical engineering students. Methodologies and design of embedded systems. Topics include software and platform foundations as well as practical design methods. Letter grading.

Mr. Potokar; Mr. Srivastava

M213B. Energy-Aware Computing and Cyber-Physical Systems. (4) (Same as Electrical and Computer Engineering M202B.) Lecture, four hours; outside study, eight hours. Requisite: course M51A or Electrical and Computer Engineering M16. Recommended: courses 111, and M151B or Electrical and Computer Engineering M116C. System-level power management and cross-layer methods for power and energy consumption in computing and communication at various scales ranging across embedded, mobile, personal, sensor, and datacenter-scale systems. Computing, networking, sensing, and control technologies and algorithms for improving energy sustainability in human-cyber-physical systems. Topics include modeling and simulation of 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


217A. Internet Architecture and Protocols. (4) Lecture, four hours; outside study, eight hours. Enforced 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 routing, fair queuing, including IP over ATM, transport protocols, routing protocols, DNS, NTP, and security protocols such as DNSSEC, to understand principles behind design of these protocols, appreciate their design tradeoffs, and learn lessons from their operations. Letter grading.

Ms. Zhang (Not offered 2018-19)

217B. Advanced Topics in Internet Research. (4) Lecture, four hours; outside study, eight hours. Enforced 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 routing, fair queuing, including IP over ATM, transport protocols, routing protocols, DNS, NTP, and security protocols such as DNSSEC, to understand principles behind design of these protocols, appreciate their design tradeoffs, and learn lessons from their operations. Letter grading.

Ms. Zhang (Not offered 2018-19)

218. Advanced Computer Networks. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 112, 118. Review of seven-layer Internet architecture, results in networking tocolos, 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.

Ms. Zhang (Not offered 2018-19)

219. Current Topics in Computer System Modeling Analysis. (4) Lecture, four hours; outside study, four hours. Review of current literature in area of computer system modeling analysis in which in-
233A. Parallel Programming. (4) Lecture, four hours; outside study, six hours. Requisite: course 131. Mutual exclusion and resource allocation in distributed systems; primitives for parallel computation; specification of parallelism, interprocess communication and atomic actions, binary and multeway rendezvous; synchronous and asynchronous languages: CSP, Ada, Linda, Maisie, UC, and others; introduction to parallel program verification. Letter grading. Mr. Milstein

233B. Verification of Concurrent Programs. (4) Lecture, four hours; outside study, eight hours. Requisite: course 233A. Formal techniques for verification of concurrent programs. Topics include safety, liveness, and finite state assertion-based techniques, weakest precondition semantics, Hoare logic, temporal logic, UNITY, and axiomatic semantics for selected parallel languages. Letter grading.

234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requisite: course 181. Introduction to theory and practice of formal methods for design and analysis of concurrent and embedded systems. Winter is devoted to algorithms for checking logical properties of hardware and software systems. Topics include semantics of reactive systems, invariant verification, temporal logic model checking, omega automation, state space reduction techniques, compositional and hierarchical reasoning. Letter grading. Mr. Majumdar

235. Advanced Operating Systems. (4) Lecture, four hours. Preparation: C or C++ programming experience. Requisite: course 111. In-depth investigation of operating systems issues through guided construction of research operating system for PC machines and consideration of recent literature. Memory management and protection, interrupts and traps, processor architectures, process scheduling, unprotected multitasking, file systems. Virtualization, networking, profiling, researching operating systems. Series of laboratory projects, including extra challenge work. Letter grading. Mr. Eggert

236. Computer Security. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 116. 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 networks, honeypots), virus and worm protection, assurance and testing, sign of secure programs, privacy, applying security principles to realistic problems, and new and emerging threats and security tools. Letter grading. Mr. Palberg, Mr. Reiter

C237A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 131. How 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 paradigms—functional, object-oriented, and logic programming by exploring the implementation 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 C151A. Letter grading. Mr. Milstein

C237B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisite: course C237A. Study of various programming language designs, from computing history and research literature, that attempt to address problems of software systems that are bloated, buggy, and difficult to maintain and extend despite trend in computing toward ever higher levels of abstraction for programming. Hands-on experience designing, prototyping, and evaluating new languages, language abstractions, and/or programming environments. Concurrently scheduled with course C257A. Letter grading. Mr. Milstein

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

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

240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; discussion, two hours. Requisites: courses 143, 240A. Logical models for data and knowledge representations. Rule-based languages and nonmonotonic reasoning. Temporal queries, spatial queries, and procure in data tabas and object relational databases (ORDBs). Abstract data types and user-defined column func tions in ORDB. Data mining algorithms. Semistruc tured information. Letter grading. Mr. Zaniolo

241B. Pictorial and Multimedia Database Management. (4) Lecture, three and one half hours; discussion, three minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Multimedia data: alphanumeric, long text, images/videos, and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and access through an alphanumeric, image, 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. File allocation, intelligent directory design, transaction management, deadlock detection and resolution, commit protocol, and commit protocols, semantic query answering, multi database systems, fault recovery techniques, network partitioning, example, trade-offs, and design for large-scale databases. Letter grading. Mr. Parker, Mr. Zaniolo (Not offered 2018-19)

245. Big Data Analytics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 143 or 180 or equivalent. With unprecedented rate at which data is being collected today in almost all fields of human endeavor, there is emerging economic and scientific need to extract useful information from it. Data analytics is process of automatic discovery of patterns, changes, associations, and anomalies in massive databases, and is highly inter-disciplinary field representing confluence of several disciplines, including database systems, data warehousing, data mining, machine learning, statistics, algorithms, data visualization, and cloud computing. Survey of main topics in big data analytics and latest advances, as well as wide spectrum of applications such as bioinformatics, E-commerce, environmental study, financial market study, multimedia data processing, network monitoring, social media analysis. Letter grading.

246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 240B or equivalent junior or senior standing. Concept and design of large search engines, large-scale search engines, and search algorithms. Overview of large-scale information retrieval. Study of Web characteristics and new management techniques for large-scale information retrieval. How to design large systems for the Web environment. Topics include Web measuring techniques, large-scale data mining algorithms, efficient page refresh techniques, Web search engine design, algorithm processing techniques on independent data sources. Letter grading.

247. Advanced Data Mining. (4) Lecture, four hours; outside study, eight hours. Requisite: course 145 or M252A. Introduction to advanced data mining algo rithms, and techniques of data mining on different types of datasets, covering basic data mining algo rithms, advanced topics on text mining, recommender systems, and graph/network mining. Team-based project involving hands-on practice of mining useful knowledge from large data sets is required. Letter grading.

249. Current Topics in Data Structures. (2 to 12) Lecture, four hours; outside study, eight hours. Requisite: course 145. Review of current literature in area of data structures in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading.

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

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


252A. Advanced Scalable Architectures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 251A. State-of-the-art scalable multiprocessors. Interdependency among implementation technology, chip microarchi tectures, and system architecture. High-performance building blocks, such as chip multiprocessors (CMPs). On-chip and off-chip communication. Mechanisms for exploiting parallelism at multiple levels. Current research areas. Examples of chips and sys tems. Letter grading. Mr. Tamir (Not offered 2018-19)

M258A. Design of VLSI Circuits and Systems. (4) (Same as Electrical and Computer Engineering M216A.) Lecture, four hours; discussion, two hours; laboratory, four hours; outside study, eight hours. Requisites: course M51A or Electrical and Computer Engineering M16, and Electrical and Computer Engineering M115A. Recommended: Electrical and Computer Engineering M258A. Design of instruction-set processors and system design and application in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading.
M258C. LSI in Computer System Design. (4) (Same as Electrical and Computer Engineering M216C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Prerequisites: course M258A. LSI/LSI design and application in computer systems. In-depth study of various architectural and VLSI design tools. Letter grading.

258F. Physical Design Automation of VLSI Systems. (4) Lecture, four hours; outside study, eight hours. Detailed study of various physical design automation tools: Logic synthesis, placement, floorplanning, routing, various design methodologies, channel and switchbox routing, planar routing and via optimization, partitioning, compaction, and other optimization techniques, as network flows, Steiner trees, simulated annealing, and genetic algorithms. Letter grading. Mr. Cong

258G. Logic Design of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Prerequisites: courses M51A, 180. Detailed study of various problems in logic/synthesis of VLSI digital systems, including two-level Boolean network optimization; multiple-level circuit optimization; artificial intelligence techniques for synthesis; and symbolic and statistical approaches to logic synthesis. Letter grading.

258H. Analysis and Design of High-Speed VLSI Interconnects. (4) Lecture, four hours; outside study, eight hours. Requisites: courses M258A, 258F. Detailed study of various problems in analysis and design of high-speed VLSI interconnections at both integrated circuit (IC) and packaging levels, including interconnect topology and management, lossless and lossy transmission lines, cross-talk and power distribution networking, and power dissipation models, interconnect topology and geometry optimization, and clocking for high-speed systems. Letter grading. Mr. Cong

259. Current Topics in Computer Science: System Design/Architecture. (4) Lecture, four hours; outside study, eight hours. Review of current literature in the area of computer science designed in which the instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. Letter grading. F,W,S

260. Machine Learning Algorithms. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 180. Problems of identifying patterns in data. Machine learning allows computers to learn potentially complex patterns from data and to make decisions based on these patterns. The course covers fundamentals of machine learning that will provide students with the ability to encode knowledge in machine learning models. Students will learn to reason about complex statistical assumptions and encode knowledge in machine learning models. Survey of key applications in natural language processing, graph mining, computer vision, and computational biology. Letter grading.

M268. Machine Perception. (4) (Same as Electrical and Computer Engineering M258H.) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for graduate students. Computational aspects of processing visual and other sensory information, unified treatment of neural representation and machine. Integration of symbolic and iconic representations in process of image segmentation. Computing multimodal sensory information by neural-net architectures. Letter grading. Mr. Soatto

268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for 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, memory, cognition, 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 practicum in area of artificial intelligence in which the instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. Mr. Terzopoulos

C274C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 174A. Introduction to computer animation, including basic principles of motion modeling, forward and inverse kinematics, and dynamic motion capture, computer vision and machine learning. Integration of symbolic and iconic approaches in the design of computer animation systems, and related applications. Letter grading. Mr. Terzopoulos

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enforced prerequisite: course 174A. Recommended course: 161. Introduction to the field of artificial life, including simple and complex systems, and motor control. Concurrently scheduled with course C2174C. Letter grading. Mr. Terzopoulos


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

263A. Language and Thought. (4) Lecture, four hours; outside study, eight hours. Requisite: course 130 or 131 or 161. Introduction to natural language processing (NLP), with emphasis on semantics. Presentation of process models for various tasks, including question answering, paraphrasing, machine translation, word-sense disambiguation, and semantic parsing. Letter grading.

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

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


M266R. Statistical Computing and Inference in Vision and Cognition. (4) (Same as Statistics M263B.) 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. Probabilistic Programming and Relational Learning. (4) Lecture, four hours; outside study, eight hours. Introduction to computational models of probability and statistical models of relational data. Study of relational representations such as probabilistic databases, relational graphical models, and Markov logic networks, as well as various probabilistic programming languages. Covers their syntax and semantics, probabilistic inference problems, parametrization and structure learning, and the computational and theoretical properties of representation and inference. Excessive statistical modeling, how to formalize and reason about complex statistical assumptions and encode knowledge in machine learning models.

268S. Seminar: Computational Neuroscience. (2) Seminar, two hours; outside study, four hours. Designed for 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, memory, cognition, 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 practicum in area of artificial intelligence in which the instructor has developed special proficiency as a consequence of research interests. Students report on selected topics. May be repeated for credit with topic change. Letter grading. Mr. Terzopoulos

C274C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 174A. Introduction to computer animation, including basic principles of motion modeling, forward and inverse kinematics, and dynamic motion capture, computer vision and machine learning. Integration of symbolic and iconic approaches in the design of computer animation systems, and related applications. Letter grading. Mr. Terzopoulos

275. Artificial Life for Computer Graphics and Vision. (4) Lecture, four hours; outside study, eight hours. Enforced prerequisite: course 174A. Recommended course: 161. Introduction to the field of artificial life, including simple and complex systems, and motor control. Concurrently scheduled with course C2174C. Letter grading. Mr. Terzopoulos

M276A. Pattern Recognition and Machine Learning. (4) Lecture, four hours; outside study, three hours; discussion, one hour. Designed for graduate students. Fundamental concepts, theories, and algorithms for pattern recognition and machine learning that are important in computer vision, image processing, speech recognition, data mining, statistics, and computational biology. Topics include Bayesian decision theory, parametric and nonparametric learning, graph-based complexity (VC-dimension, MDL, AIC), PCA/ICA/TCA, MDS, SVD, clustering, S/U or letter grading. Mr. Zhu

280A-280Z. Algorithms. (Each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department. Selections from language grammars, machines, operators; pushdown automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Substitutes of some current sections: Principles of Design and Analysis (280A); Graphs and Networks (280G). May be repeated for credit with consent of instructor and topic change. Letter grading.

280AP. Approximation Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180. Background in discrete mathematics helpful. Theoretical and practical techniques for working with Hard problems. Inability to solve these problems efficiently means algorithmic techniques are based on approximation—finding solution that is near to best possible in efficient running time. Coverage of approximation techniques for number of different problems, with algorithm design techniques that include primal-dual method, linear program rounding, greedy algorithms, and local search. Letter grading.

281A. Computability and Complexity. (4) Lecture, four hours; outside study, eight hours. Requisite: course 180 or compatible background. Concepts fundamental to study of discrete information systems and theory of computing, with emphasis on regular sets of strings, Turing-recognizable (recursively enumerable) sets, closure properties, machine characterizations, nondeterminisms, decidability, unsolvable problems, “easy” and “hard” problems, PTIME/NP-time. Letter grading. Mr. Ostrovsky (Not offered 2018-19)

M282A. Cryptography. (4) Same as Mathematics M209A.) Lecture, four hours; outside study, eight hours. The theory of cryptography, stressing rigorous definitions and proofs of security. Topics include notions of hardness, one-way functions, hard-core bits, pseudorandom generators, pseudorandom functions and pseudorandom permutations, public-key cryptography and private-key encryption, secret-sharing, message authentication, digital signatures, interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commitment protocols, key-agreement, contract signing, and two-party secure computation with static security. Letter grading. Mr. Ostrovsky (F)

M282B. Cryptographic Protocols. (4) Same as Mathematics M209B.) Lecture, four hours; outside study, eight hours. Requisite: course M282A. Consideration of advanced cryptographic protocol design and analysis. Topics include noninteractive zero-knowledge proofs; zero-knowledge arguments; concurrent zero-knowledge; zero-knowledge proofs; IP=PSPACE proof, stronger notions of security for public-key encryption, including chosen-plaintext and ciphertext security; secure multiparty computation; dealing with dynamic adversary, non-redeemability and composability of secure protocols; software protection; threshold cryptography; identity-based cryptography; private information retrieval; protection against man-in-the-middle attacks; zero-knowledge protocols; identification protocols; digital cash schemes; lower bounds on use of cryptographic primitives, software obfuscation. May be repeated for credit with topic change. Letter grading. Mr. Ostrovsky (Sp)


284A-284ZZ. Topics in Automata and Languages. (4) Each) Lecture, four hours; outside study, eight hours. Requisite: course 180. Additional requisites for each offering announced in advance by department.  Selections from context-free languages and grammars, machines, operators; pushdown automata, context-free languages and their generalizations, parsing; multidimensional grammars, developmental systems; machine-based complexity. Substitutes of some current and planned sections: Context-Free Languages (284A), Parsing Algorithms (284P). May be repeated for credit with consent of instructor and topic change. Letter grading. Mr. Sahai (Not offered 2018-19)

CM286. Computational Systems Biology: Modeling and Simulation of Biological Systems. (5) (Same as Bioengineering CM286.) Lecture, four hours; outside study, eight hours. Dynamic biosystems modeling and computer simulation methods for studying biological/biomedical processes and systems at multiple levels of organization. Control system, multicompartamental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organizational levels. Both theory and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of numerical simulation algorithm for systems biology with exercises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading. Mr. DiStefano (Not offered 2018-19)

CM287. Research Communication in Computational and Systems Biology. (4) (Same as Bioengineering CM287.) Lecture, four hours; outside study, eight hours. Requisite: course CM286. Closely directed, interactive, and real research experience in academic or industrial 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 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 (Not offered 2018-19)

288S. Seminar: Theoretical Computer Science. (2) Seminar, two hours; outside study, six hours. Requisite: courses 280A, 281A. Intended for students undertaking research. Discussion of advanced topics and current research in such areas as algorithms and complexity models for parallel and concurrent computation, and formal language and automata theory. May be repeated for credit. S/U grading.

289A-289ZZ. Current Topics in Computer Theory. (2 to 12 each) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer theory in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. Letter grading.

CM290C. Complexity Theory. (4) Lecture, four hours; outside study, eight hours. Diagonalization, polynomial-time hierarchy, PNP theorem, randomness and de-randomization, circuit complexity, attempts and limitations to proving P does not equal NP, average-case complexity, one-way functions, hardness amplification. Problem sets and presentation of previous and current research related to course topics. Letter grading. Mr. Sahai (F)

289OA. Online Algorithms. (4) Lecture, four hours; outside study, eight hours. Requisite: course 280. Introduction to decision making under uncertainty and competitive analysis. Exploration of online algorithms for problems arising in many areas, such as data and memory management, searching and navigating in unknown terrains, and server systems. Letter grading.

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

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

M296B. Optimal Parameter Estimation and Experimental Design for Biomedical Systems. (4) (Same as Bioengineering M296B, Biometrics M270, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biometrics 220. Estimation methodology and model parameter estimation algorithms for finding dynamic systems 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 experimental design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano

M296C. Advanced Topics and Research in Bio-medical Systems Modeling and Computing. (4) (Same as Bioengineering M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course CM286 or M296A or Biometrics 220. Estimation methodology and model parameter estimation algorithms for finding dynamic systems 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 experimental design via applications in physiology and pharmacology. Letter grading. Mr. DiStefano

M296D. Introduction to Computational Cardiology. (4) (Same as Bioengineering M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186. Introduction to mathematical modeling and computer simulation of cardiac 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 supercomputers, choice of numerical algorithms, to optimize accuracy and provide computational stability. Letter grading. Mr. DiStefano

298. Research Seminar: Computer Science. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate and senior science students. Discussion of advanced topics and current research in algorithmic processes that describe and transform information: theory, analysis, design, efficiency, implementation, and application. May be repeated for credit. S/U grading. (F,Sp)
**Electrical and Computer Engineering**

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Baybars Y. Koerding, Ph.D., Vice Chair, Computer Engineering
Mona Jarrahi, Ph.D., Vice Chair, Graduate Affairs
C.-K. Ken Yang, Ph.D., Vice Chair, Industry Relations

**Associate Professors**

Vijay K. Dhir, Ph.D.
Yuanxun Ethan Wang, Ph.D.
Yue Song, Ph.D.

**Assistant Professors**

Chandrashekhar J. Joshi, Ph.D.
Diana L. Huffaker, Ph.D.
Gabor C. Temes, Ph.D.
Izhak Rubin, Ph.D.

**Adjunct Professors**

Ezio Biglieri, Ph.D.
Sudhakar Pamarti, Ph.D.

**Adjunct Assistant Professors**

Pedram Khalis, Ph.D.
Sherwin Mouloudi, Ph.D.

**Scope and Objectives**

Electrical and computer engineers are responsible for inventions that have revolutionized our society, such as the electrical grid, telecommunications, and automated computing and control. The profession continues to make vital contributions in many domains, such as the infusion of information technology into all aspects of daily life. To further these ends, the Department of Electrical and Computer 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
Electrical and Computer Engineering / 81

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.

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 telecommunication, control systems, signal processing, data science, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, and solid-state electronics.

The program grants two undergraduate degrees (Bachelor of Science in Electrical Engineering and Bachelor of Science in Computer 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 and Computer 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 industry and government agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

Electrical Engineering Undergraduate Program Educational Objectives


The electrical engineering curriculum provides an excellent background for either graduate study or employment. Undergraduate education in the department provides students with (1) fundamental knowledge in mathematics, physical sciences, and electrical engineering, (2) the opportunity to specialize in specific areas of interest or career aspiration, (3) intensive training in problem solving, laboratory skills, and design skills, and (4) a well-rounded education that includes communication skills, the ability to function well on a team, an appreciation for ethical behavior, and the ability to engage in lifelong learning. This education is meant to prepare students to thrive and to lead. It also prepares them to achieve the following two program educational objectives: (1) that graduates of the program have successful technical or professional careers and (2) that graduates of the program continue to learn and to adapt in a world of constantly evolving technology.

Computer Engineering Undergraduate Program Educational Objectives

The undergraduate computer engineering program prepares students to be able to (1) understand fundamental computing concepts and make valuable contributions to the practice of computer engineering; (2) design, analyze, and implement complex computer systems for a variety of application areas and cyberphysical domains; (3) demonstrate the ability to work effectively in a team and communicate their ideas; (4) continue to learn as part of a graduate program or otherwise in the 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.

The Computer Engineering major is a designated capstone major that is jointly administered by the Computer Science and Electrical and Computer Engineering departments. 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. 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 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 integrated circuits, embedded systems, photonic devices, automatic computation and control, and telecommunication devices and systems.

Students are encouraged to make use of their electrical and computer 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. See the elective examples and suggested tracks below.

Learning Outcomes

The Electrical Engineering major has the following learning outcomes:

- Application of knowledge of mathematics, science, and engineering
- Design of a system, component, or process to meet desired needs within realistic constraints
- Function as a productive member of a multidisciplinary team
- Effective communication
- Identification, formulation, and solution of electrical engineering problems

Preparation for the Major

Required: Chemistry and Biochemistry 20A; Computer Science 31, 32; Electrical and Computer Engineering 2, 3, 10, 11L, M16 (or Computer Science M51A); Mathematics 31A, 31B, 32A, 32B, 33A, 33B; Physics 1A, 1B, 1C, 4AL, 4BL.
The Major

Required: Electrical and Computer Engineering 101A, 102, 110, 111L, 113, 131A; six core courses selected from Computer Science 33, Electrical and Computer Engineering 101B, 115A, 121B, 132A, 133A, 141, 170A; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 12 units of major field elective courses, at least 8 of which must be upper-division electrical and computer engineering courses—the remaining 4 units may be from upper-division electrical and computer engineering courses or from another UCLA Samueli department; and one two-term electrical and computer engineering capstone design course (8 units).

Electrical and Computer Engineering 100 and CM182 may not satisfy elective credit.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Elective Examples

Communications Systems: Studies range from basic wave propagation to point-to-point links up to large-scale networks for both wired and wireless applications. Students might take 12 units selected from Electrical and Computer Engineering 132A, 132B, 133A, 134, and M171L, and 8 capstone design units from 113DA/113DB or 180DA/180DB.

Control Systems and Optimization: The study of how to control a variety of systems ranging from a single physical system to continental networks, such as the electrical grid. Students might take 12 units selected from Electrical and Computer Engineering 112, 133A, 133B, 134, 141, and 142 and 8 capstone design units from 113DA/113DB or 184DA/184DB.

Electromagnetic Systems: Topics include the fundamentals of electromagnetic wave propagation in guided systems and free space, antennas, and radio systems. Students might take 12 units selected from Electrical and Computer Engineering 101B, 162A, 163A, and 163C and 8 capstone design units from 163DA/163DB or 164DA/164DB.

Embedded Computing: The study of compact systems that include collections of integrated circuits that interact with the physical world for purposes such as sensing and control in applications as diverse as appliances, automobiles, and medicine. Students might take 12 units selected from Electrical and Computer Engineering 115A, 115C, M116C, M116L, M119, and 142 and 8 capstone design units from 180DA/180DB or 183DA/183DB.

Integrated Circuits: The study of how to achieve large-scale integration of thousands to billions of computational, memory, and sensing elements in single or multichip modules. Students might take 12 units selected from Electrical and Computer Engineering 115A, 115AL, 115B, 115C, and 115E and 8 capstone design units from 164DA/164DB or 183DA/183DB.

Photonics and Plasma Electronics: The study of how to manipulate light and plasmas to create devices such as those that enable high-speed optical communication systems. Students might take 12 units selected from Electrical and Computer Engineering 170A, 170B, 170C, and M185 and 8 capstone design units from 173DA/173DB.

Simulation and Data Analysis: The study of how to derive meaningful inferences from measured data, such as speech, images, or other data, after conversion from analog to digital form. Students might take 12 units selected from Electrical and Computer Engineering 114, 133A, 133B, 134, and M146 and 8 capstone design units from 113DA/113DB.

Signal Processing: The study of how to derive meaningful inferences from measured data, such as speech, images, or other data, after conversion from analog to digital form. Students might take 12 units selected from Electrical and Computer Engineering 114, 133A, 133B, 134, and M146 and 8 capstone design units from 113DA/113DB or 180DA/180DB.

Solid-State and Microelectromechanical Systems (MEMS) Devices: The study of the nanoscale and microscale devices that are the base of modern computation and sensing systems. Students might take 12 units selected from Electrical and Computer Engineering 121B, 123A, 123B, 128, and M153 and 8 capstone design units from 121DA/121DB.

Suggested Tracks

The technical breadth area requirement provides an opportunity to combine elective courses in the Electrical Engineering major with those from another UCLA Samueli major to produce a specialization in an interdisciplinary domain. Students are free to design a specialization in consultation with a faculty adviser.

Bioengineering and Informatics (BI) refers to the design of biomedical devices and the analysis of data derived from such devices and instruments. Students might take Chemistry and Biochemistry 20B and two courses from Bioengineering 100, C101, CM102, and 110 and/or 12 units from Computer Science CM121, Electrical and Computer Engineering 114, 133B, 134, and 176 and 8 capstone design units from 180DA/180DB.

Computer Engineering (CE) concentrates on the part of the hardware/software stack related to the design of new processors and the operation of embedded systems. Students might take a 12-unit technical breadth area in computer science such as Computer Science 111, 117, 130, and 180 and/or 12 units of electives from Electrical and Computer Engineering 115C, M116C, M116L, M119, 132B, and M146 and 8 capstone
design units from 113DA/113DB or 180DA/180DB or 183DA/183DB.

Cyber Physical Systems (CPS) refer to networked systems that include sensors and actuators that interact with the physical world. They blend embedded systems with networking and control and include, for example, robotic systems and the Internet of things (IoT). Students might take a 12-unit technical breadth area in computer science such as Computer Science 111, 117, and 180 and/or 12 units of electives from Electrical and Computer Engineering M116C, 132B, and 142 and 8 capstone design units from 183DA/183DB.

**Computer Engineering B.S.**

**Capstone Major**

The undergraduate curriculum provides all computer engineering students with preparation in the mathematical and scientific disciplines that lead to a set of courses that span the fundamentals of the discipline in the major areas of data science and embedded networked systems. These collectively provide an understanding of many inventions of importance to our society, such as the Internet of things, human-cyber-physical systems, mobile/wearable/implantable systems, robotic systems, and more generally smart systems at all scales in diverse spheres. The design of hardware, software, and algorithmic elements of such systems represents an already dominant and rapidly growing part of the computer engineering profession. Students are encouraged to make use of their computer science and electrical and computer engineering electives and a two-quarter capstone design course to pursue deeper knowledge within one of these areas according to their interests, whether for graduate study or preparation for employment.

**Learning Outcomes**

The Computer Engineering major has the following learning outcomes:

- Application of mathematical, scientific, and engineering knowledge
- Design of a software or hardware system, component, or process to meet desired needs within realistic economic, environmental, social, ethical, health, safety, security, reliability, manufacturability, and sustainability constraints
- Function productively on a team with others
- Identification, formulation, and solution of engineering problems
- Effective communication

**Preparation for the Major**

**Required:** Computer Science 1 (or Electrical and Computer Engineering 1), 31, 32, 33, 35L, M51A (or Electrical and Computer Engineering M16); Electrical and Computer Engineering 3; Engineering 96C; Mathematics 31A, 31B, 32A, 32B, 33A, 33B, 61; Physics 1A, 1B, 1C, and 4AL or 4BL.

**The Major**

**Required:** Computer Science 111, 118 (or Electrical and Computer Engineering 132B), M151B (or Electrical and Computer Engineering M116C), M152A (or Electrical and Computer Engineering M116L), 180; Electrical and Computer Engineering 100, 102, 113, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, Statistics 100A; 8 units of computer science and 8 units of electrical and computer engineering upper-division electives; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; 8 units capstone design from either Electrical and Computer Engineering 180DA/180DB or 183DA/183DB.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or [https://www.registrar.ucla.edu/Academics/GE-Requirement](https://www.registrar.ucla.edu/Academics/GE-Requirement).

**Suggested Tracks**

**Networked Embedded Systems:** This track targets two related trends that have been a significant driver of computing, namely stand-alone embedded devices becoming networked and coupled to physical systems, and the Internet evolving toward a network of things (the IoT). These may broadly be classified as cyber physical systems, and includes a broad category of systems such as smart buildings, autonomous vehicles, and robots, which interact with each other and other systems. This trend in turn is driving innovation both in the network technologies (new low-power wireless networks for connecting things, and new high-speed networks and computing infrastructure to accommodate the transport and processing needs of the deluge of data resulting from continual sensing), and in embedded computing (new hardware and software stack catering to requirements such as ultra-low power operation, and embedded machine learning).

Students pursuing this track are strongly encouraged to take Electrical and Computer Engineering M119 or Computer Science M119 in junior year, and to choose three electives from courses such as Computer Science 117, 130, 131, 132, 133, 136, 181, 188, Electrical and Computer Engineering 2, 115A, 115B, 132A, 133A, 141, 142, 188.

Students who pursue a technical breadth area in either electrical and computer engineering or computer science can choose an additional three courses from this list.

**Data Science:** This track targets the trend toward the disruptive impact on computing systems, both at the edge and in the cloud, of massive amounts of sensory data being collected, shared, processed, and used for decision making and control. Application domains such as health, transportation, energy, etc. are being transformed by the abilities of inference-making and decision-making from sensory data that is pervasive, continual, and rich. This track will expose students to the entire data-to-decision pathway spanning the entire stack from hardware and software to algorithms, applications, and user experience.

Students pursuing this track are strongly advised to take Computer Science 143 and M146 or Electrical and Computer Engineering M146, and to additionally choose two electives from courses such as Computer Science CM121, 136, 144, 145, 161, 188, Electrical and Computer Engineering 114, 133A, 133B, 134, 188.

Students who pursue a technical breadth area in either electrical and computer engineering or computer science can choose an additional three courses from this list.

Students are also free to design ad hoc tracks. The technical breadth area requirement provides an opportunity to combine elective courses in electrical and computer engineering and computer science with those from another UCLA Samueli major to produce a specialization in an interdisciplinary domain. As noted above, students can also select a technical breadth area in either Electrical and Computer Engineering or Computer Science to deepen their knowledge in either discipline.

**Graduate Study**

For information on graduate admission see Graduate Programs on page 25.

The following introductory information is based on 2018-19 program requirements for UCLA graduate degrees. Complete program requirements are available at [https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/](https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/). 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 Electrical and Computer 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. The minimum requirements for the M.S. degree are as follows:

1. **Requisite.** B.S. degree in Electrical Engineering or a related field

2. All M.S. program requirements should be completed within two academic years from admission into the M.S. graduate program in the Henry Samueli School of Engineering and Applied Science

3. Students must maintain a minimum cumulative grade-point average of 3.0 every term and 3.0 in all graduate courses

4. **Thesis Option.** Students selecting the thesis option must complete at least the following requirements: (a) five formal graduate courses to serve as the major field of study, (b) two formal graduate courses to serve as the minor field of study, (c) Electrical and Computer Engineering 297, (d) two Electrical and Computer Engineering 598 courses involving work on the M.S. thesis, (e) no other 500-level courses, other seminar courses, nor Electrical and Computer 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 and Computer Engineering 297, (d) Electrical and Computer 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 and Computer 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 and Computer 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 and Computer 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 and Computer Engineering 201A, 201C, M202A, M202B, 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. Courses include Computer Science 251A, 252A, Electrical and Computer Engineering 215A through 215E, M216A, 221A, 221B

**Physical and Wave Electronics Area Tracks**

1. **Electromagnetics Track.** Courses deal with electromagnetic theory; propagation and scattering; antenna theory and design; microwave and millimeter wave circuits; printed circuit antennas; integrated and fiber optics; microwave-optical interaction, antenna measurement, and diagnostics; numerical and asymptotic techniques; satellite and personal communication antennas; periodic structures; genetic algorithms; and optimization techniques. Courses include Electrical and Computer Engineering 221C, 260A, 260B, 261, 262, 263, 266, 270

2. **Photonics and Plasma Electronics Track.** Courses deal with laser physics, optical amplification, electro-optics, acoustooptics, magneto-optics, nonlinear optics, photonic switching and modulation, ultrafast phenomena, optical fibers, integrated waveguides, photodetection, optoelectronic integrated circuits, optical microelectromechanical systems (MEMS), analog and digital signal transmission, photonics sensors, lasers in biomedicine,
fundamental plasma waves and instabilities; interaction of microwaves and laser radiation with plasmas; plasma diagnostics; and controlled nuclear fusion. Courses include Electrical and Computer Engineering 270, 271, 272, 273, 274, 285A, 285B, M287

3. Solid-State and Microelectromechanical Systems (MEMS) Devices Track. Courses deal with solid-state physical electronics, semiconductor device physics and design, and microelectromechanical systems (MEMS) design and fabrication. Courses include Electrical and Computer Engineering 221A, 221B, 221C, 222, 223, 225, M250B, Mechanical and Aerospace Engineering 281, 284, C287L

Signals and Systems Area Tracks

1. Communications Systems Track. Courses deal with communication and telecommunication principles and engineering applications; channel and source coding; spread spectrum communication; cryptography; estimation and detection; algorithms and processing in communication and radar; satellite communication systems; stochastic modeling in telecommunication engineering; mobile radio engineering; and telecommunication switching, queuing systems, communication networks, local-area, metropolitan-area, and wide-area computer communication networks. Courses include Electrical and Computer Engineering 205A, 210A, 230A through 230D, 231A, 231E, 232A through 232E, 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 and Computer Engineering 205A, M208B, M208C, 210B, 236A, 236B, 236C, M237, M240A, M240C, 241A, M242A


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 and computer 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 and computer 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. 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. 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 and Computer Engineering 297, (c) one technical communications course such as Electrical and Computer Engineering 295, (d) no 500-level courses, other seminar courses, nor Electrical and Computer 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 under the direction of the faculty adviser, and (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
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. The written qualifying examination is known as the Ph.D. preliminary 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 and Computer 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

Students who fail the examination may repeat it once only with consent of the departmental graduate adviser. The preliminary examination, together with the course requirements for the Ph.D. program, should be completed within two years from admission into the program.

After passing the written qualifying examination described above, students are ready to take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus.

Facilities and Programs

Computing Resources

The department maintains a server room with several racks of computer and storage servers in addition to computing resources within individual faculty labs. The network infrastructure supports a variety of Windows, UNIX, and Linux servers, workstations, and laptops. The school also offers access to a computing cluster primarily used for undergraduate and graduate teaching purposes. The campus supplies free access to a large-scale computing cluster (Hoffman2) with over 13,000 computing cores on over 1200 server nodes. Archival-class backup storage is also available through the campus.

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 Heterogeneous Integration and Performance Scaling (CHIPS)

The UCLA Center for Heterogeneous Integration and Performance Scaling (CHIPS) addresses emerging technologies, design, and architectures to achieve a more holistic Moore’s Law for the overall system. The center’s core activities include advanced heterogeneous hardware integration technologies; methodologies and tools relying on fine-pitch interconnects on both rigid and flexible substrates; wafer-scale integration; active and passive components for advanced systems; and large-scale systems especially for cognitive, memory, and medical engineering applications.

CHIPS is multidisciplinary, integrating specialties and students in diverse areas including electrical engineering, materials science and engineering, mechanical engineering, computer science and engineering, and biosciences, with strong industry participation. The center has extensive fabrication facilities to support these activities.

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)
The 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 and Computer Engineering 163DA and 164DB, special projects classes such as Electrical and Computer Engineering 199, and/or research projects, have the opportunity to obtain experimental and design experience in the following technology areas: integrated microwave circuits and antennas, integrated millimeter wave circuits and an-tennas, numerical visualization of electromagnetic waves, electromagnetic scattering and radar cross-section measurements, and antenna near field and diagnostics measurements.

Nanoelectronics Research Facility

http://www.nanolab.ucla.edu

The state-of-the-art Nanoelectronics Research Facility (NRF) for graduate research and teaching, as well as the undergraduate microelectronics teaching laboratory, are housed in an 8,500-square-foot class 100/100 class 100 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.

Photonics and Optoelectronics Laboratories

Students in the Laser Laboratory study the properties of lasers and gain an understanding of the application of this modern technology to optics, communication, and holography.

The Photonics and Optoelectronics Laboratories include facilities for research in all of the basic areas of quantum electronics. Specific areas of experimental investigation include high-powered lasers, nonlinear optical processes, ultrafast lasers, parametric frequency conversion, electro-optics, infrared detection, and semiconductor lasers and detectors. Operating lasers include mode-locked and Q-switched Nd:YAG and Nd:YLF lasers, Ti:Al2O3 lasers, ultraviolet and visible wavelength argon lasers, wavelength-tunable dye lasers, as well as gallium arsenide, helium-neon, excimer, and high-powered continuous and pulsed carbon dioxide laser systems. Also available are equipment and facilities for research on semiconductor lasers, fiber optics, nonlinear optics, and ultrashort laser pulses. These laboratories are open to undergraduate and graduate students who have faculty sponsorship for their thesis projects or special studies.

Plasma Electronics Facilities

Two laboratories are dedicated to the study of the effects of intense laser radiation on matter in the plasma state. One, located in Engineering IV, houses a state-of-the-art tabletop terawatt (T3) 400fs laser system that can be operated in either a single or dual frequency mode for laser-plasma interaction studies. Diagnostic equipment includes a ruby laser scattering system, a streak camera, and optical spectrographs and multi-channel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing.

The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2 radiation, focuseable 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-pincher 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 X5660 CPUs and 48 GB of RAM, and three Nvidia M2070 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. Peak system performance is approximately 300TF/150TF (single/double precision) with a measured Linpack performance of 68.1TF (double precision). DAWSON 2 is housed within the UCLA Institute for Digital Research Engineering data center.

Solid-State Electronics Facilities

Solid-state electronics equipment and facilities include a modern integrated semiconductor device processing laboratory, complete new Si and III-V compound molecular beam epitaxy systems, CAD and maskmaking facilities, lasers for beam crystallization study, thin film and characterization equipment, deep-level transient spectroscopy instruments, computerized capacitance-voltage and other characterization equipment, including doping density profiling systems, low-temperature facilities for material and device physics studies in cryogenic
temperatures, optical equipment, including many different types of lasers for optical characterization of superlattice and quantum well devices, and characterization equipment for high-speed devices, including 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)
Benjamin M. Wu, D.D.S, Ph.D. (Bioengineering), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), 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.

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 collaborators include 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 Heterogeneous Integration and Performance Scaling (CHIPS)
• Center for High-Frequency Electronics (CHFE)
• Center for Nanoscience Innovation for Defense (CNID)
• Center of Excellence in Green Nanotechnology (CEGN)
• Functional Engineered Nano Architectonics Focus Center (FENA)
• Plasma Science and Technology Institute
• Translational Applications of Nanoscale Multiferroic Systems (TANMS)
• WN Institute of Neurotronics (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 in 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 (Razavi)
• Complex Networks Group (Roychowdhury)
• Cyber-Physical Systems Laboratory (Tabuada)
• Device Research Laboratory (K. Wang)
• Digital Microwave Laboratory (E. Wang)
• Energy and Electronic Design Automation Laboratory (He)
• 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)
• Interconnected and Integrated Bioelectronics Laboratory (28BL) (Enamnejad)
• Laboratory for Embedded Machines and Ubiquitous Robotics (Mehta)
• Laser-Plasma Group (Joshi)
• MedAdvance: Machine Learning and Artificial Intelligence for Medicine (van der Schaar)
• Mesoscopic Optics and Quantum Electronics Laboratory (Wong)
• Microwave Electronics Laboratory (Itoh)
• Nanoelectronics Research Center (Candler)
• Nanostructure Devices and Technology Laboratory (Chui)
• Nanosystems Computer-Aided Design Laboratory (Gupta)
• Networked and Embedded Systems Laboratory (Sivaswamy)
• Neuroengineering Group (Markovic)
• Optoelectronics Circuits and Systems Laboratory (Jalali)
• Optoelectronics Group (Yablonovitch)
• Public Safety Network Systems Laboratory (Yao, Rubin)
• Quantum Electronics Laboratory (Stafstrom)
• Robust Information Systems Laboratory (Dolecek)
• Sensors and Technology Laboratory (Candler)
• Signal Processing and Circuit Electronics Group (Pamarti)
• Speech Processing and Auditory Perception Laboratory (Alwan)
• Terahertz Devices and Intersubband Nanostructures Group (Williams)
• Terahertz Electronics Laboratory (Jarrahi)
• Visual Machines Group (Kadambi)
• Wireless Integrated Systems Research Group (Daneshrad)

Faculty Areas of Thesis Guidance

Professors
Asad A. Abidi, Ph.D. (UC Berkeley, 1981)  High-performance analog electronics, device modeling
Bahram Jalali, Ph.D. (Columbia, 1989)
RF photonics, integrated optics, fiber optic inte-
grated circuits
Mona Jarrahi, Ph.D. (Stanford, 2007)
Radio frequency (RF), microwave, millimeter-
wave, and terahertz circuits, high-frequency
device and system integration, integrated photonics and
optoelectronics
Chandrashekhar J. Joshi, Ph.D. (Hull U., England,
1978)
Laser fusion, laser acceleration of particles,
nonlinear optics, high-power lasers, plasma
physics
William J. Kaiser, Ph.D. (Wayne State, 1983)
Research and development of new microsen-
or and microinstrument technology for indus-
try, science, and military applications; model-
development and applications of new atomic-
resolution scanning probe microscopy methods for
microelectronic device research
Kuo-Nan Liu, Ph.D. (New York U., 1971)
Radiative transfer, remote sensing of clouds and
ecosystems and climate/clouds-aerosols
research
Jia-Ming Liu, Ph.D. (UCLA, 1987)
Laser and charged particle beam-plasma inter-
actions, advanced accelerator concepts,
advanced light sources, laser-fusion, high-
energy density science, high-performance
computing, plasma physics
Scientific computing, applied mathematics
Aydogan Ozcan, Ph.D. (Stanford, 2005)
Bioimaging, nano-photonics, nonlinear optics
Sudhakar Pamarla, Ph.D. (UCLA San Diego, 2003)
Mixed-signal IC design, signal processing and
communication theory
Gregory J. Pottie, Ph.D. (McMaster U., Canada,
1998)
Communication systems and theory with appli-
cations to wireless sensor networks
Yahya Rahmat-Samii, Ph.D. (U. Illinois, 1975)
Satellite communications antennas, personal
communication antennas including human
interactions, advanced remote sensing and
radio astronomy applications, advanced
numerical and genetic optimization techniques in
electromagnetics, frequency selective sur-
faces and photonic band gap structures, novel
integrated and fractal antennas, near-field
antenna measurements and diagnostic tech-
niques, electromagnetic theory
Behzad Razavi, Ph.D. (Stanford, 1992)
Analog, RF, and mixed-signal integrated circuit
design, dual-standard RF transceivers, phase-
locked loops and frequency synthesizers, A/
D and D/A converters, high-speed data com-
munication circuits
Wenli P Roychowdhury, Ph.D. (Stanford, 1989)
Models of computing including parallel and
distributed processing systems, quantum com-
puting and communication processing, circuits,
and computing paradigms for nano-electronics
and molecular electronics, adaptive and learn-
ing algorithms, nonparametric methods and
algorithms for large-scale information process-
ing, combinatorics and complexity, and infor-
mation theory
Izhak Rubin, Ph.D. (Princeton, 1970)
Telecommunications and computer communica-
tions systems and networks, mobile wireless
networks, multimedia IP networks, UAV/UGV-
aided networks, integrated system and network
management, CAISR systems and networks,
optical networks, network simulations and anal-
ysis, traffic modeling and engineering
Henry Samueli, Ph.D. (UCLA, 1980)
VLSI implementation of signal processing and
digital communication systems, high-speed
digital signal processing and digital filter design
Ali H. Sayed, Ph.D. (Stanford, 1992)
Adaptive systems, statistical and digital signal
processing, estimation theory, signal process-
ing for communications, linear system theory,
interplays between signal processing and con-
trol methodologies, fast algorithms for large-
scale problems
Stefano Soatto, Ph.D. (Caltech, 1996)
Computer vision, systems and control theory,
detection and estimation, robotics, system
identification, shape analysis, motion analysis,
image processing, video processing, autono-
mous systems
Jason L. Speyer, Ph.D. (Harvard, 1968)
Statistical and information theory, optimal
control and estimation with application to aerospace
systems; guidance, flight control, and flight
mechanics
Mari B. Srivastava, Ph.D. (U. Berkeley, 1992)
Wireless networking, embedded computing,
networked embedded systems, sensor net-
works, mobile and ubiquitous computing, low-
power and power-aware systems
Paulo Tabuada, Ph.D. (Technical U. Lisbon, Portu-
gal, 2002)
Real-time, networked, embedded control sys-
tems; mathematical systems theory including
discrete-event, timed, and hybrid systems;
geometric nonlinear control; algebraic/categori-
cal methods
Lieve Vandenberghe, Ph.D. (Katholieke U. Leu-
ven, Belgium, 1992)
Optimization in engineering and applications in
systems and control, circuit design, and signal
processing
Miehala van der Schaar, Ph.D. (Eindhoven U.,
Technology, Netherlands, 2001)
Multimedia processing and compression, multi-
media networking, multimedia communications,
multimedia architectures, enterprise multimedia
streaming, mobile and ubiquitous computing
John D. Villasenor, Ph.D. (Stanford, 1989)
Communications, signal and image proces-
sing, 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
Yuanxun Ethan Wang, Ph.D. (U. Texas Austin,
1999)
Smart antennas, RF and microwave power
amplifiers, numerical techniques, DSP tech-
niques for microwave systems, phased arrays,
wireless and radar systems, microwave inte-
grated circuits
Richard D. Wiesel, 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
Ultrafast and nonlinear optics, quantum commu-
nications and computing, chip-scale opto-
electronics, precision measurements and sensing
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
Assistant Professors


- Human-computer interaction, sensing and interaction techniques, intelligent interactive systems, computational design and fabrication

Sam Ermanninaj, Ph.D. (Stanford, 2014)

- Biological and chemical sensors, wearable and flexible electronics, MEMS and NEMS fabrication microfluidics, internet of things devices, technology development for personalized/precision medicine

Achuta Kadambi, Ph.D. (MIT, 2018)

- Computational imaging, computer vision, robotics, medical devices

Ankur Mehta, Ph.D. (UC Berkeley, 2012)

- Robotics and electromechanical systems design, fabrication, and control; wireless sensor networks hardware and applications; systems integration

Adjunct Professors

Ezio Biglieri, Dr. Ing. (Politecnico di Torino, Italy, 1967)

- Digital communication, wireless channels, modulation, error-control coding, signal processing in telecommunications

Darshu 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, iterative decoding

Dan M. Goebel, Ph.D. (UCLA, 1981)

- Electric propulsion, high-efficiency ion and Hall thrusters, cathodes, high-voltage engineering, microwave devices and microwave communications, pulsed power

Diana L. Huffaker, Ph.D. (U. Texas Austin, 1995)

- Solid-state nanotechnology, MWIR optoelectronic devices, solar cells, S photonics, novel materials

Asad M. Madni, Ph.D. (California Coast U., 1987)

- Development and commercialization of intelligent sensors and systems, RF and microwave instrumentation, signal processing

Yi-Chi Shih, Ph.D. (U. Texas Austin, 1982)

- Microwave/millimeter-wave active 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

Ell 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

Chi On Chui, Ph.D. (Stanford, 2004)

- Nanoelectronic and optoelectronic devices and technology, heterostructure semiconductor devices, monolithic integration of heterogeneous technology, exploratory nanotechnology

Adjunct Senior Professors

Pedram Khali Amiri, Ph.D. (Delft U. Technology, Netherlands, 2008)

- Nanoelectronics, spintronics, nano-magnetism and nonvolatile memory and logic

Shervin Moloudi, Ph.D. (UCLA, 2008)

- Telecommunication analog and high-frequency circuit design

Zachary Taylor, Ph.D. (UC Santa Barbara, 2009)

- Biomedical optics, imaging system design, novel contrast-generation mechanisms

Lower-Division Courses

1. Undergraduate Seminar. (1) Formerly numbered Electrical Engineering 1.) Seminar, one hour; outside study, two hours. Introduction by faculty members and industry lecturers to electrical engineering disciplines through current applications of autonomous systems and vehicles, biomedical devices, aerospace electronic systems, consumer products, data science, and entertainment products (amusement rides, etc.), as well as energy generation, storage, and transmission. P/NP grading.

2. Physics for Electrical Engineers. (4) Formerly numbered Electrical Engineering 2.) 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 electronics in solids. Discussion of electrical characteristics of semiconductors leading to operation of junction devices. Letter grading.

3. Introduction to Electrical Engineering. (4) Formerly numbered Electrical Engineering 3.) Lecture, two hours; laboratory, two hours; outside study, eight hours. Introduction to field of electrical engineering. Basic circuits techniques with application to explanation of electrical engineering inventions such as telecommunication, 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.

10. Circuit Theory I. (4) Formerly numbered Electrical Engineering 10.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 (or Computer Science 1 or Materials Science 10), Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced only for Computer Science and Engineering and Electrical Engineering majors), Mathematics 33B, Physics 1C. Introduction to circuit analysis. Resistive circuits, capacitors, inductors and ideal transformers, Kirchhoff laws, node and loop analysis, first-order circuits, second-order circuits, Thévenin and Norton theorems, ideal steady state. Letter grading.

10H. Circuit Theory I (Honors). (4) Formerly numbered Electrical Engineering 10H.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 3 (or Computer Science 1 or Materials Science 10), Mathematics 33A, Physics 1B. Corequisites: course 11L (enforced only for Computer Science and Engineering and Electrical Engineering majors), Mathematics 33B. Honors course parallel to course 10. Letter grading.

11L. Circuits Laboratory I. (1) Formerly numbered Electrical Engineering 11L.) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced corequisite: 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.

11L. Circuits Laboratory I. (Honors). (1) Formerly numbered Electrical Engineering 11HL.) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced corequisite: 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.

M16. Logic Design of Digital Systems. (4) Formerly numbered Electrical Engineering M16B.) (Same as Computer Science M51A.) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to digital systems. Specification and implementation of combinational and sequential systems. Standard logic modules and programmable logic arrays. Specification and implementation of algorithmic systems; data and control sections. Number systems...

Mr. Srivastava (F, W, 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 illustrating many paths of discovery at UCLA. P/NP grading.

18. Honors Seminars. (1) Seminar, three hours. Limited to 20 students. Designed as adjunct to lower-division lecture course. Exploration of topics in greater depth and breadth. supervised reading, papers, other activities and led by lecture course instructor. May be applied toward honors credit for eligible students. Honors content noted on transcript. P/NP or letter grading. Four hours.

Mr. Bote

19. 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 minor of 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper-Division Courses

100. Electrical and Electronic Circuits. (4) (Formerly numbered Electrical Engineering 100.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: Mathematics 33A and 33B, Mechanical and Aerospace Engineering 82, 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 diodes and transistors, small signal models, and operational amplifiers. Letter grading. Mr. Razavi (F, W, Sp)

101A. Engineering Electromagnetics. (4) (Formerly numbered Electrical Engineering 101A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 32A and 32B, or 33A and 33B, Physics 1C. Electromagnetic field concepts, waves and phasors, transmission lines and Smith chart, transient responses, vector analysis, introduction to Maxwell equations, static and quasi-static electric and magnetic fields. Letter grading.

Mr. Joshi, Mr. Williams (F, W)

101B. Electromagnetic Waves. (4) (Formerly numbered Electrical Engineering 101B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101A. Time-varying fields and potentials, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and antennas. Letter grading.

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


Ms. Fragouli (F, W, Sp)

110. Circuit Theory II. (4) (Formerly Electrical Engineering 110.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: courses 10, M16 (or Computer Science M51A). Corequisite: course 111L. Analysis and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illustrating many paths of discovery at UCLA. P/NP grading.

Mr. Srivastava (F, W, Sp)

110H. Circuit Theory II (Honors). (4) (Formerly numbered Electrical Engineering 110H.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 10, M16 (or Computer Science M51A). Corequisite: course 111L. Analysis and critical thinking about topics of current intellectual importance, taught by faculty members in their areas of expertise and illustrating many paths of discovery at UCLA. P/NP grading.

Mr. Abidi (Sp)

110L. Circuits Measurements Laboratory. (2) (Formerly numbered Electrical Engineering 110L.) Lecture, one hour; laboratory, one hour; outside study, two hours. Enforced requisites: courses 10, 111L. Equipment and procedures for measurement of electrical quantities, linear circuit elements, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.

Mr. Abidi, Mr. Pamarti (W)

111L. Circuits Laboratory II. (1) (Formerly numbered Electrical Engineering 111L.) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced requisites: courses 10, 111L. Corequisite: course 111L. Equipment and procedures for measurement of electrical quantities, linear circuit elements, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.

Mr. Abidi, Mr. Pamarti (W)

111L. Circuits Laboratory II. (1) (Formerly numbered Electrical Engineering 111L.) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced requisites: courses 10, 111L. Corequisite: course 111L. Equipment and procedures for measurement of electrical quantities, linear circuit elements, semiconductor diodes and transistors, small signal models, and operational amplifiers. Letter grading.

Mr. Abidi, Mr. Pamarti (W)

112. Introduction to Power Systems. (4) (Formerly numbered Electrical Engineering 112.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 111L. Analysis and critical overview of organization and operation of interconnected power systems. Development of appropriate models for interconnected power systems and learning how to perform power flow, economic dispatch, and short circuit analysis. Introduction to power system transient dynamics. Letter grading.

Mr. Tabuada (Not offered 2018-19)


Ms. Fragouli, Ms. van der Schaar (W, Sp)

113DA-113DB. Digital Signal Processing Design. (4-4) (Formerly Electrical Engineering 113DA-113DB) Real-time implementation of digital signal processing algorithms on digital processor chips. Experiments involving A/D and D/A conversion, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for communications, speech, audio, or voice processing DSP chips. 113DA. Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 113. In progress grading (credit to be given only on completion of course 113DB). 113DB. Laboratory, four hours; outside study, eight hours. Enforced requisite: courses 113, 113DA. Completion of projects begun in course 113DA. Letter grading.

Mr. Daneshrad (113DA in F, W, Sp; 113DB in W, Sp)

114. Speech and Image Systems Design. (4-4) (Formerly numbered Electrical Engineering 114.) Lecture, three hours; discussion, one hour; laboratory, two hours; outside study, six hours. Enforced requisite: course 111L. Design concepts of speech and image processing systems. Speech production, analysis, and modeling in first half of course; design techniques for image enhancement, filtering, and transformation in second half. Lab: lecture supplement.

Mr. Daneshrad (113DA in F, W, Sp; 113DB in W, Sp)


Mr. Abidi, Mr. Daneshrad (F, Sp)

115AL. Analog Circuits Laboratory I. (2) (Formerly numbered Electrical Engineering 115AL.) Laboratory, four hours; discussion, one hour; outside study, seven 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)


Mr. Abidi (W)

115C. Digital Circuits. (4) (Formerly numbered Electrical Engineering 115C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 110 or 115A, and Computer Science M51A. Transistor-level digital circuit analysis and design. Modern logic families (static CMOS, pass-transistor, dynamic logic), integrated circuit (IC) layout, digital circuits (logic gates, flip-flops, latches, counters, etc.), computer-aided simulation of digital circuits. Letter grading.

Mr. Markovic (W, Sp)

115E. Design Studies in Electronic Circuits. (4) (Formerly numbered Electrical Engineering 115E.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 115B. Description of process of circuit design through lectures to complement other laboratory-based design courses. Topics vary by instructor and include communication circuits, power electronics, and instrumentation and measurement and may entail simulation-based design projects. Emphasis throughout on design-oriented analysis and rigorous approach to practical circuit design. Letter grading. Mr. Abidi (Sp)

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

Mr. Gupta (F, Sp)

M116L. Introductory Digital Design Laboratory. (2) (Formerly numbered Electrical Engineering M116L.) (Same as Computer Science M152A) 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 using programmed array logic, design projects. Letter grading.

Mr. He (F, W, Sp)
121B. Principles of Semiconductor Device Design. (4) (Formerly numbered Electrical Engineering 121B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: course 2. Introduction to principles of operation of modern MOS transistors, equivalent circuits, high-frequency behavior, voltage limitations. Letter grading.

Mr. Wang (F) 121DA-121DB. Semiconductor Processing and Device Design. (4-4) (Formerly numbered Electrical Engineering 121DA-121DB.) Design fabrication and characterization of p-n junction and transistors. Students perform various processing tasks such as wafer preparation, 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. Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisite for course 121B. In progress grading (credit to be given only on completion of course 121DB).

121DB. Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: courses 121A, 121B. Letter grading. Mr. K.L. Wang (in W; 121DB in Sp)


Mr. K.L. Wang (F) 123B. Fundamentals of Solid-State II. (4) (Formerly numbered Electrical Engineering 123B.) Lecture, four hours; discussion, eight hours; outside study, eight hours. Enforced requisite: course 123A. Discussion of solid-state properties, lattice vibrations, thermal properties, dielectric, magnetic, and superconducting properties. Letter grading.

Mr. K.L. Wang (Sp) 128. Principles of Nanoelectronics. (4) (Formerly numbered Electrical Engineering 128.) Lecture, four hours; discussion, four hours; outside study, four hours. Enforced requisite: Physics 1C. Introduction to fundamentals of nanoscience for electronics nanosystems. Principles of fundamental quantities: electron charge, effective mass, Bohr magneton, and spin, as well as theoretical approaches. From these nanoscale components, behaviors of nanoscale devices such as analysis of dynamics, variability, and noise, contrasted with those of scaled CMOS. Incorporation of design project in which students are challenged to design electronics nanosystems. Letter grading.

Mr. K.L. Wang (Sp)

131A. Probability and Statistics. (4) (Formerly numbered Electrical Engineering 131A.) Lecture, four hours; discussion, one hour; outside study, ten hours. Enforced requisites: course 102 (enforced), Mathematics 32B, 33B. Introduction to basic concepts of probability, including random variables and vectors, distributions and densities, moments, characteristic functions, and limit theorems to communications control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading.

Mr. Roychowdhury (F/W) 132A. Introduction to Communication Systems. (4) (Formerly numbered Electrical Engineering 132A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102, 113, 131A. Review of basic probability, basic laws of random variables, and random processes. Signal processing, digital modulation, transmission of data through telephone lines and computer buses. Principles of operation of digital communication systems. Letter grading.

Mr. Digiovanni (SP/W) 132B. Data Communications and Telecommunication Networks. (4) (Formerly numbered Electrical Engineering 132B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A. Layered communications architectures. Queueing system modeling and analysis. Error control, flow and congestion control. Packetswitching, circuit switching, and routing. Network performance analysis and design. Multiple-access communications. TDMA, FDMA, polling, random access. Local, metropolitan, wide area, integrated services networks. Letter grading.

Mr. Rubin (F)


Mr. Rubin (F) 133B. Simulation, Optimization, and Data Analysis. (4) (Formerly numbered Electrical Engineering 133B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 133A. Linear algebra; bounds on error; iterative methods for solving linear equations; conditioning and stability; complexity. Interpolation and approximation; splines. Zeros and roots of nonlinear equations. Linear least squares and orthogonal QR factorization; statistical interpretation. Numerical optimization; Newton-Raphson; numerical quadrature. Solving ordinary differential equations. Eigenvalues and singular values; QR algorithm; statistical applications. Letter grading.

Mr. Vandenberghe (F) 134. Graph Theory in Engineering. (4) (Formerly numbered Electrical Engineering 134.) Lecture, four hours; discussion, one hour; outside study, seven hours. Basics of graph theory, including trees, bipartite graphs and matching, vertex and edge coloring, planar graphs and networks. Emphasis on reducing real-world engineering systems to graph theory for analysis and design. Letter grading.

Mr. Vandenberghe (Not offered 2018-19)
eight hours. Enforced requisites: courses 101A, 101B, 163DA. Limited to senior Electrical Engineering majors. Capstone design course, with emphasis on transmission line-based circuits and components to address need in industry for design and development capability. Offered in Fall and Winter. Required of all senior EE majors. Limited to senior Electrical Engineering majors. Capstone design course, with emphasis on transmission line-based circuits and components to address need in industry for design and development capability. Offered in Fall and Winter. Required of all senior EE majors. Limited to senior Electrical Engineering majors.

163DA. Microwave and Wireless Design II. (4) (Formerly numbered Electrical Engineering 163DB.) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisites: courses 101A, 101B, 163DA. Limited to senior Electrical Engineering majors. Design of wireless systems. Introduction to advanced topics related to mobile and personal communication systems in different frequency bands. Communication systems, wireless networks, and their applications. Offered in Spring. Required of all senior EE majors. Please consult with course instructor for prerequisites.

173DA-173DB. Photonics and Communication Design. (4-4) (Formerly numbered Electrical Engineering 173DA-173DB.) Lecture, one hour; laboratory, three hours; outside study, eight hours. Enforced requisites: course 115B. Course 164DA is enforced requisite to 164DB. Limited 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, using trade-offs across sub-systems while meeting constraints and optimizing metrics related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results required. In Progress grading (credit to be given only on completion of course 173DB). 173DA. Enforced requisites: courses 101A, 173DA. Finalization of design and testing of projects begun in course 173DA. Letter grading. Mr. Stafsudd (Not offered 2018-19)

176. Photonics in Biomedical Applications. (4) (Formerly numbered Electrical Engineering 176.) Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: course 101A. Study of different types of optical systems and their physical background. Examination of their roles in current and projected biomedical applications. Specific capabilities of photonics to be related to each example. Letter grading. Mr. Ozcan (Sp)

180DA-180DB. Systems Design. (4-4) (Formerly numbered Electrical Engineering 180DA-180DB.) 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 widely among students. Required of all senior EE majors. Limited to senior Electrical Engineering majors. Introduction to advanced topics in electrical engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic not previously covered. Letter grading. Mr. Mori (W)
Graduate Courses

201A. VLSI Design Automation. (4) (Formerly numbered Electrical Engineering 201A) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 115C. Fundamentals of design automation of VLSI circuits and systems, including introduction to circuit and system platforms such as field programmable gate arrays and multicore systems; high-level synthesis, logic synthesis, and technology mapping; physical design; and testing and verification. Letter grading. (Formerly numbered Electrical Engineering 201A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 115C. Detailed study of VLSI circuit and system models, circuit performance, signal integrity, power and thermal effects, reliability, and manufacturability. Discussion of principles of modeling and optimization codevelopment. Letter grading. Mr. Kaiser (Not offered 2018-19)

101D. Design in Nanoscale Technologies. (4) (Formerly numbered Electrical Engineering 201D.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 115C. Challenges of digital circuit design and layout in deep nanoscale 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 (F)

M202A. Embedded Systems. (4) (Formerly numbered Electrical Engineering M202A.) (Same as Computer Science M213A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Design, and for graduate computer science and electrical engineering students. Methodologies and technologies for design of embedded systems. Topics include hardware/software codesign and design of 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 and software architecture optimization. Theoretical foundations as well as practical design methods. Letter grading. Mr. Srivastava (Not offered 2018-19)

M202B. Energy-Aware Computing and Cyber-Physical Systems. (4) (Formerly numbered Electrical Engineering M202B.) (Same as Computer Science M213B.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course M16 or Computer Science M51A. Recommended: course M116C or Computer Science M115B, and Computer Science 2. System-level-tempered cross-layer method for power and energy consumption in computing and communication at various scales ranging across embedded, mobile, personal, enterprise, and datacenter scales. Computing, sensing, and control technologies and algorithms for improving energy sustainability in human-cyber-physical systems. Topics include modeling of energy consumption, energy sources, energy storage, dynamic power management; power-performance scaling and energy proportionality; duty-cycling; power-aware scheduling, load-balancing, and management; thermal management; sensing of power consumption. Letter grading. Mr. Srivastava (Not offered 2018-19)

M202C. Networked Embedded Systems Design. (4) (Formerly numbered Electrical Engineering 202C.) 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 combined embedding hardwired platform, embedded operating system, and hardware/software interface. Essential graduate student background for research and industrial experience in wireless devices for applications ranging from conventional wireless mobile devices to new area of wireless health. Laboratory design modules and course projects based on state-of-the-art embedded platform. Letter grading. Mr. Kaiser (Not offered 2018-19)

205A. Matrix Analysis for Scientists and Engineers. (4) (Formerly numbered Electrical Engineering 205A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Designed for first-year graduate students in all branches of engineering, science, and related disciplines. Introduction to matrix theory; and linear algebra which are central to all of modern science and engineering is conducted. Review of matrices taught in undergraduate courses and introduction to graduate-level topics. Letter grading. Mr. Vandenberghe (F)

M206. Machine Perception. (4) (Formerly numbered Electrical Engineering M206.) (Same as Computer Science M268.) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for graduate students. Computational aspects of perceiving visual and other sensory information. Unified treatment of early vision in man and machine. Integration of symbolic and iconic representations in process of computer vision. Computational methods and sensory information by neural-net architectures. Letter grading. Mr. Soatto (F)

M208B. Functional Analysis for Applied Mathematics and Engineering. (4) (Formerly numbered Electrical Engineering 208B.) (Same as Mathematics M286A.) Lecture, four hours; outside study, eight hours. Requisites: course 208A (or Mathematics 115A and 115B), Mathematics 131A, 131B, 132. Topics may include: Banach and separable spaces; Fourier transforms; linear functionals. Riesz representation theory, linear operators and their adjoints; self-adjoint and compact operators. Spectral theory. Differential operators such as Laplacian and Green’s functions. Semigroups. Applications. S/U or letter grading. Mr. Mr. Sayed (Not offered 2018-19)


M209A. Special Topics in Circuits and Embedded Systems. (4) (Formerly numbered Electrical Engineering 209A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Special 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 or letter grading. Mr. Pamarti (F, W, Sp)

209BS. Seminar: Circuits and Embedded Systems. (2 to 4) (Formerly numbered Electrical Engineering 209BS.) Seminar, two to four hours; outside study, four to eight hours. Seminars are 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 or letter grading. Mr. Pamarti (F, W, Sp)

210A. Adaptation and Learning. (4) (Formerly numbered Electrical Engineering 210A) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: prior training in probability theory, random processes, and linear algebra. Recommended requisites: courses 205A, 241A. Mean-square estimation and filters, least-squares estimation and filters, steepest-descent algorithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance analyses for adaption and learning, and classification and optimization. Letter grading. Mr. Sayed (Not offered 2018-19)


211A. Digital Image Processing I. (4) (Formerly numbered Electrical Engineering 211A) Lecture, three hours; discussion, one hour; laboratory, four hours; outside study, four hours. Preparation: computer programming experience. Requisite: course 208A or Mathematics 115A and 115B. Mathematics 131A, 131B, 132. Topics may include: fundamentals of image acquisition and representation. Semigroups with compact resolvents. Analytic semigroups and spectral representation. Semigroups with compact resolvents. Parabolic and hyperbolic systems. Controllability and stabilizability. Spectral theory of differential operators, PDEs, generalized functions. S/U or letter grading. Mr. Mr. Sayed (Not offered 2018-19)


M214A. Digital Speech Processing. (4) (Formerly numbered Electrical Engineering 214A) (Same as Bioengineering M214A.) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 113. Theory and applications of digital processing of speech signals. Mathematical models of human speech production and perception mechanisms, speech analysis and synthesis, and various applications include linear prediction, filter-bank models, and morphemic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Mr. Ms. Alwan (W)

214B. Advanced Topics in Speech Processing. (4) (Formerly numbered Electrical Engineering 214B) Lecture, three hours; discussion, one hour; computer laboratory assignments, two hours; outside study, six hours. Requisite: course M214A. Advanced techniques used in various speech-processing applications, with
focus on speech recognition by humans and machines. Required: Psychophysics, hearing, and perception. Dynamic Time Warping (DTW) and Hidden Markov Models (HMM) for automatic speech recognition systems, pattern classification, and search algorithms. Aids for hearing impaired students. Letter grading.

Ms. Alwan (Sp)

215A. Analog Integrated Circuit Design. (4) (Formerly numbered Electrical Engineering 215A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 215A. Analysis of design of analog integrated circuits, MOS and bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, noise-figure, distortion, sampling and discrete-time circuits, bandgap references. Letter grading.

Mr. Abidi, Mr. Razavi (F)

215B. Advanced Digital Integrated Circuits. (4) (Formerly numbered Electrical Engineering 215B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 115C, 215B. Analysis and design of analog integrated circuits, MOS and bipolar device structures and models, single-stage and differential amplifiers, noise, feedback, operational amplifiers, noise-figure, distortion, sampling and discrete-time circuits, bandgap references. Letter grading.

Mr. Yao (W)

216C. Analog Integrated Circuit Design. (4) (Formerly numbered Electrical Engineering 216C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 216A. Principles of RF circuit and system design, with emphasis on monolithic implementation in VLSI technologies, circuit design of transceiver architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading.

Mr. Abidi, Mr. Razavi (W)

215D. Analog Microsystem Design. (4) (Formerly numbered Electrical Engineering 215D.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 215A. Analysis and design of data conversion interfaces and filters. Sampling circuits, signal processing, D/A and A/D conversion, switched-capacitor circuits, precision techniques, discrete- and continuous-time filters. Letter grading.

Mr. Abidi, Mr. Razavi (Sp)

215E. Signaling and Synchronization. (4) (Formerly numbered Electrical Engineering 215E.) Lecture, four hours; outside study, eight hours. Requisites: courses 215A, 216A. Analysis and design of circuits for synchronization and communication for VLSI systems. Use of both digital and analog design techniques to improve data rate of electronic systems between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance wire-line, fiber-optic, transmitters, receivers, and timing recovery circuits. Letter grading.

Mr. Pamarti (Sp)

M216A. Design of VLSI Circuits and Systems. (4) (Formerly numbered Electrical Engineering 216A.) (Same as Computer Science M258A.) Lecture, four hours; discussion, two hours; laboratory, four hours; outside study, two hours. Requisites: courses 16 or Computer Science M51A, and 115A. Recommended: course 215A. Principle of VLSI design and implementation in computer systems. Fundamental design techniques that can be used to implement complex integrated circuits on chips. Letter grading.

Mr. Markovic (F)

216B. VLSI Signal Processing. (4) (Formerly numbered Electrical Engineering 216B.) Lecture, four hours; discussion, one hour; outside study, eight hours. Advanced concepts in VLSI signal processing, with emphasis on architecture and design optimization within block-based circuit design standards. 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 applications.

Mr. Markovic (Sp)

M216C. LSI in Computer System Design. (4) (Formerly numbered Electrical Engineering 216C.) (Same as Computer Science M258C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Course M216A. LSI/ VLSI design and implementation in computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading.

Not offered 2018-19

M217. Biomedical Imaging. (4) (Formerly numbered Electrical Engineering M217.) (Same as Bioengineering M217.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 114 or 211A. Optical imaging modalities in biomedicine. Other nonoptical imaging modalities discussed briefly for comparison. Letter grading.

Mr. Ozcak (W)

218. Network Economics and Game Theory. (4) (Formerly numbered Electrical Engineering 218.) Lecture, four hours; discussion, one hour; outside study, seven hours. Discussion of different cooperative and noncooperative games among agents can be constructed to model, analyze, optimize, and shape emerging interactions among users in different networks and system settings. How strategic agents can successfully compete with each other for limited and time-varying resources by optimizing their decision process and learning from their past interaction with other agents. To develop their optimal action strategies in these distributed, informationally decentralized environments, agents need to learn and model directly or implicitly other agents’ responses to their actions. Discussion of existing modeling techniques and learning through games, including adjustment processes for learning equilibria, fictitious play, regret-learning, and more. Letter grading.

Mr. van der Schaar (W)

219. Large-Scale Data Mining: Models and Algorithms. (4) (Formerly numbered Electrical Engineering 219.) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction of various tools and techniques for learning from large data bases, including regularized linear models, nonparametric and kernel techniques, regression, and Bayesian graphical models. Emphasis on techniques to evaluate relative performance of different methods and their applicability. Includes computer projects that explore entire data analysis and modeling cycle: collecting and cleaning large-scale data, deriving predictive and causal models, and evaluating performance of different models. Letter grading.

Dr. N. K. Choudhury (W)

221A. Physics of Semiconductor Devices I. (4) (Formerly numbered Electrical Engineering 221A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Physical principles and design considerations of junction diodes, transistors, and gate-controlled devices. Letter grading.

Mr. Yao (Sp)

221B. Physics of Semiconductor Devices II. (4) (Formerly numbered Electrical Engineering 221B.) Lecture, four hours; discussion, one hour; outside study, eight hours. Principles and design considerations of field effect devices and charge-coupled devices. Letter grading.

Mr. K.L. Wang, Mr. Yao (W)

221C. Microwave Semiconductor Devices. (4) (Formerly numbered Electrical Engineering 221C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Physical principles and design considerations of microwave solid-state devices: Schottky barrier mixer diodes, IMPATT diodes, trans- ferred electron devices, tunnel diodes, microwave transistors. Letter grading.

Mr. K.L. Wang, Mr. Yao (Not offered 2018-19)

222. Integrated Circuits Fabrication Processes. (4) (Formerly numbered Electrical Engineering 222.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 2. Principles of integrated circuits fabrication processes. Technolo- gies and materials used in VLSI fabrication include bulk crystal and epitaxial growth, thermal oxi- dation, diffusion, ion-implantation, chemical vapor deposition, dry etching, lithography, and metaliza- tion. Introduction of advanced process simulation tools. Letter grading.

Mr. Yao (Sp)


Mr. Wang (F)

224. Solid-State Electronics II. (4) (Formerly numbered Electrical Engineering 224.) Lecture, four hours; discussion, eight hours. Prerequisite: course 223. Techniques to solve Boltzmann transport equa- tion, various scattering mechanisms in semiconduc- tor nanostructures, field transistors and semiconduc- tor switches. Monte Carlo method in transport. Optical pro- perties. Letter grading.

Mr. K.L. Wang (W)

225. Physics of Semiconductor Nanostructures and Devices. (4) (Formerly numbered Electrical Engineering 225.) Lecture, four hours; outside study, eight hours. Prerequisite: course 223. Theoretical methods for calculating electronic and optical properties of semiconductor nanostructures, Quantum size effect and localization in quantum nanostructures in semicon- ductor nanometer scale devices, including negative resistance diodes, transistors, and detectors. Letter grading.

Mr. K.L. Wang (Sp, alternate years)

229. Seminar: Advanced Topics in Solid-State Electronics. (4) (Formerly numbered Electrical Engi- neering 229.) Seminar, four hours; outside study, eight hours. Requisites: courses 223, 224. Current re- search areas, such as radiation effects in semicon- ductors, reaction-diffusion in living cells, optical and microwave semiconductor devices, nonlinear optics, and electron emission. Letter grading.

(Not offered 2018-19)

229S. Advanced Electrical Engineering Seminar. (2) (Formerly numbered Electrical Engineering 229S.) Seminar, two hours; outside study, six hours. Prereq- uisite: successful completion of PhD major field ex- amination. Seminar on current research topics in solid-state and quantum electronics (Section 1) or in electronic circuit theory and applications (Section 2). Students report on tutorial topic and on research topic in their dissertation area. May be repeated for credit. S/U grading.

(Not offered 2018-19)

230A. Detection and Estimation in Communications. (4) (Formerly numbered Electrical Engineering 230A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Applications of estimation and detection fundamentals in communication and signal processing; random signal and noise characteristics by analysis and simulations; mean square (MS) and maximum likelihood (ML) estimations and algorithms; detection under ML, Bayes, and Neyman-Pearson (NP) criteria; signal-to- noise ratio (SNR) and error probability evaluations. In- troduction to Monte Carlo simulations. Letter grading.

Mr. Yao (F)


Mr. Yao (Not offered 2018-19)

230C. Signal Processing in Communications. (4) (Formerly numbered Electrical Engineering 230C.) Lecture, four hours; outside study, eight hours. Requisites: courses 132A, 230A. Digital signal processing; implementa- tions of signal processing in communication and signal processing systems. Spectral analysis using Fourier transform and windowing, parametric models, eigen-decomposition of covariance matrices, time-frequency analysis, wavelet transform, and sub-band processing. Array processing using beamforming for
SNIR enhancement, smart antenna, and source separation and their applications to compressive sensing and applications. Letter grading.

Mr. Yao (Not offered 2018-19)

230D. Algorithms and Processing in Communication Systems. (Formerly numbered Electrical Engineering 232D.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: courses 131A, 230A. Review of computational linear algebra methods on QRD, eigen- and singular-value decompositions, and LS methods. Topics include computational linear algebra methods on QRD, eigen- and singular-value decompositions, and LS methods. Topics include decomposition and large-scale linear programs. Letter grading. Mr. Rubin (Sp)

232E. Large-Scale Social and Complex Networks: Design and Algorithms. (Formerly numbered Electrical Engineering 232E.) Lecture, four hours; discussion, one hour; outside study, seven hours. Modeling and design of large-scale complex networks, including social networks, peer-to-peer file-sharing networks, mobile networks, and gene networks. Modeling of characteristic topological features of complex networks, such as power laws and percolation threshold. Introduction to design algorithms for various applications, such as e-mail spam detection, friend recommendation, viral popularity, and epidemics. Introduction to network algorithms, computational complexity, and nondeterministic polynomial-time completeness. Letter grading.

Mr. Rubin (Sp)

233. Wireless Communications System Design, Modeling, and Implementation. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Covers algorithms, architectures, and implementation for radio transceivers, physical, and network layer functionalities. Topics include wireless channel modeling, single-carrier and multi-carrier systems, multiple antenna systems, channel characterization, and their correction, architectures and circuits design trade-offs, wideband spectrum sensing, wideband signal processing, radio massive multiple-input, multiple-output (MIMO) systems, and physical layer aspects of Internet of Things (IoT) communication. Letter grading.

234A. Networking Theory and Applications. (4) Formerly numbered Electrical Engineering 234A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A or equivalent. Research developments in new mathematical techniques for emerging large-scale, ultra-reliable, fast, and affordable data storage systems. Topics include, but are not limited to, graph-based codes and algebraic codes and decoders for modern storage devices (e.g., flash), rank modulation, rewriting codes, algorithms for data deduplication and synchronization, and redundant array of independent disks (RAID) systems. Letter grading.

Ms. Fragouli (Not offered 2018-19)

235A. Mathematical Foundations of Data Storage Systems. (4) Formerly numbered Electrical Engineering 235A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A or equivalent. Key concepts, principles, and algorithms of online learning and learning how to make decisions under uncertainty in broad context, including Markov decision processes, optimal stopping, reinforcement learning, structural results for online learning, multi-armed bandits learning, multitagent learning, multigent deep learning. Letter grading.

Mr. van der Schaar (Not offered 2018-19)

239BS. Seminar: Signals and Systems. (2 to 4) Formerly numbered Electrical Engineering 239BS.) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U or letter grading.

Ms. Fragouli (W/Sp)

239BS. Seminar: Signals and Systems. (2 to 4) Formerly numbered Electrical Engineering 239BS.) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U or graded.

Ms. Fragouli (W/Sp)

239BS. Seminar: Signals and Systems. (2 to 4) Formerly numbered Electrical Engineering 239BS.) Seminar, two to four hours; outside study, four to eight hours. Seminars and discussions on current and advanced topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U or graded.

Ms. Fragouli (W/Sp)


Mr. Vandenberghe (Not offered 2018-19)

238. Multimedia Communications and Processing. (4) Formerly numbered Electrical Engineering 238.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Key concepts, principles, and algorithms of online learning and learning how to make decisions under uncertainty in broad context, including Markov decision processes, optimal stopping, reinforcement learning, structural results for online learning, multi-armed bandits learning, multitagent learning, multigent deep learning. Letter grading.

Ms. van der Schaar (Not offered 2018-19)

239AS. Special Topics in Communication Systems. (4) Formerly numbered Electrical Engineering 239AS.) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics in one or more aspects of signals and systems, such as communications, control, image processing, information theory, multimedia, computer networking, optimization, speech processing, telecommunications, and VLSI signal processing. May be repeated for credit with topic change. S/U or letter grading. 

Ms. Fragouli (W/Sp)

M240A. Linear Dynamic Systems. (4) Formerly numbered Electrical Engineering M240A.) (Same as Chemical Engineering M280A and Mechanical and Aerospace Engineering M276.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisite: course 141 or Mechanical and Aerospace Engineering 171A. State-space description of linear time-invariant (LTI) and time-varying (LTV) systems in continuous and discrete time. Linear algebra, eigenvalues and eigenvectors, singular values, Cayley-Hamilton theorem, Jordan form; solution of state
241A. Stochastic Processes. (Formerly numbered Electrical Engineering M218B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Review of basic probability, axiomatic development, expectation, convergence of random processes: stationarity, power spectral density, Response of linear systems to random inputs. Introduction to estimation, filtering, Markov processes, martingales, etc. Basics of estimation. Special topics. (2)


M250C. Microelectromechanical Systems (MEMS) Device Physics and Design. (Formerly numbered Electrical Engineering M250C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to MEMS science and technology. Design of microsensors and actuators. Designing MEMS to be produced


M257. Nanoscience and Technology. (Formerly numbered Electrical Engineering M257.) (Same as Mechanical and Aerospace Engineering M258.) Lecture, four hours; discussion, one hour; outside study, eight hours. Introduction to fundamentals of nano science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication methods, nanomaterials, nanoelectronics, and nanobiotechnology introduction. 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. Lecture grading. Mr. Chen (W)

260A. Advanced Engineering Electrodynamics. (Formerly numbered Electrical Engineering 260A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101B, 162A. Advanced treatment of concepts in electrodynamics and their applications to modern engineering problems. Vector potential, duality, reciprocity, and equivalence theorems. Scattering from cylinder, half-plane, wedge, plane wave, pulse shaping, and characterization. Green's functions in electromagnetics and dyadic calculus. Lecture grading. Mr. Rahmat-Samii (F)


261. Microwave and Millimeter Wave Circuitry. (Formerly numbered Electrical Engineering 261.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 163A. Rectangular and circular waveguides, coupling structure, line, line, and dielectric waveguide circuits, integral equations in electromagnetics. Lecture grading. Mr. Itoh (W)


266. Computational Methods for Electromagnetics. (Formerly numbered Electrical Engineering 266.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 162A, 163A. Computational techniques for partial differential equations in engineering, finite-element, method of moments, method of lines. Applications include transmission lines, resonators, integrated circuits, solid-state device modeling, electromagnetic scattering, and antennas. Letter grading. Mr. Itoh (Sp)

270. Applied Quantum Mechanics. (Formerly numbered Electrical Engineering 270.) Lecture, four hours; discussion, one hour; outside study, seven 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, energy principle, central force problems, Hilbert spaces, WKB approximation, matrix mechanics, density matrix formalism, and radiation theory. Letter grading. Mr. Afsa (F)

271. Classical Laser Theory. (Formerly numbered Electrical Engineering 271.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 170A. Microscopic and macroscopic laser physics and application of optical equations using classical formalism. Letter grading. Mr. Yoshi (W)

272. Dynamics of Lasers. (Formerly numbered Electrical Engineering 272.) Lecture, four hours; outside study, eight hours. Requisite: course 271. Ultrafast solitary pulse generation, pulse shaping, and parametric oscillators. Pulse measurement techniques. Letter grading. Mr. Liu (Not offered 2018-19)


274. Optical Communication and Sensing Design. (Formerly numbered Electrical Engineering 274.) Lecture, three hours; outside study, nine hours. Requisites: courses 170A and 170B or equivalent. Introduction to physical layer design in fiber optic communications, interconnects, and wireless systems. Spectrum, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmission.
Electrical and Computer Engineering

**986. CM282. Science, Technology, and Public Policy.** (4) (Formerly numbered Electrical Engineering 285.) Lecture, four hours; outside study, eight hours. Limited to graduate electrical engineering students. Preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

**987. Preparation for PhD Oral Qualifying Examination.** (2 to 16) (Formerly numbered Electrical Engineering 597C.) Tutorial, to be arranged. Limited to graduate electrical engineering students. Supervised independent research for MS candidates, including thesis prospectus. S/U grading.

**988. Research for and Preparation of MS Thesis.** (2 to 12) ( Formerly numbered Electrical Engineering 598.) Tutorial, to be arranged. Limited to graduate electrical engineering students. Supervised independent research for MS candidates, including thesis prospectus. S/U grading.

**989. Research for and Preparation of PhD Dissertation.** (2 to 16) (Formerly numbered Electrical Engineering 599.) Tutorial, to be arranged. Limited to graduate electrical engineering students. Supervised independent research for MS candidates, including thesis prospectus. S/U grading.
Materials Science and Engineering

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Yong Chen, Ph.D.
Bruce S. Dunn, Ph.D. (Nippon Sheet Glass Company Professor of Materials Science)
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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.
John D. Mackenzie, Ph.D. (Nippon Sheet Glass Company Professor Emeritus of Materials Science)
Kanji Ono, Ph.D.
King-Ning Tu, Ph.D.

Associate Professors
Suneel Kodambaka, Ph.D.
Jaime Marian, Ph.D.
Gaurav Sart, Ph.D.

Assistant Professor
Ximin He, Ph.D.

Adjunct Associate Professors
Eric P. Bescher, Ph.D.
Esther H. Lan, Ph.D.
Sergey Prikhodko, Ph.D.

Scope and Objectives

At the heart of materials science and engineering is the understanding and control of the microstructure of solids. Microstructure is used broadly in reference to electronic and atomic structure of solids—and defects within them—at size scales ranging from atomic bond lengths to airplane wings. The structure of solids over this wide range dictates their structural, electrical, biological, and chemical properties. 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 undergraduate program in the Department of Materials Science and Engineering 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 (Department of Letters and Science).

The department also has a program in electronic materials that provides a broad-based background in materials science, with opportunity to specialize in the study of those materials used for electronic and optoelectronic applications. The program incorporates several courses in electrical and computer engineering in addition to those in the materials science curriculum. The graduate program allows for specialization in one of the following fields: ceramics and ceramic processing, electronic and optical materials, and structural materials.

Department Mission

The Department of Materials Science and Engineering faculty members, students, and alumni foster a collegial atmosphere to produce (1) highly qualified students through an educational program that cultivates excellence, (2) novel and highly innovative research that advances basic and applied knowledge in materials, and (3) effective interactions with the external community through educational outreach, industrial collaborations, and service activities.

Undergraduate Program Educational Objectives

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

The Materials Engineering major at UCLA prepares undergraduate students for employment and/or advanced studies within industry, the national laboratories, state and federal agencies, and academia. To meet the needs of these constituencies, the objectives of the undergraduate program are to produce graduates who (1) possess a solid foundation in materials science and engineering, with emphasis on the fundamental scientific and engineering principles that govern the microstructure, properties, processing, and performance of all classes of engineering materials, (2) understand materials processes and the application of general natural science and engineering principles to the analysis and design of materials systems of current and/or future importance to society, (3) have strong skills in independent learning, analysis, and problem solving, with special emphasis on design of engineering materials and processes, communication, and an ability to work in teams, and (4) understand and are aware of the broad issues relevant to materials, including professional and ethical responsibilities, impact of materials engineering on society and environment, contemporary issues, and need for lifelong learning.

Undergraduate Study

The Materials Engineering major is a designated capstone major. Students undertake two individual projects involving materials selection, treatment, and serviceability. Successful completion requires working knowledge of physical properties of materials and strategies and methodologies of using materials properties in the materials selection process. Students learn and work independently and practice leadership and teamwork in and across disciplines. They are also expected to communicate effectively in oral, graphic, and written forms.

Materials Engineering B.S.

Capstone Major

The materials engineering program is designed for students who wish to pursue a professional career in the materials field and desire a broad understanding of the relationship between microstructure and properties of materials. Metals, ceramics, and polymers, as well as the design, fabrication, and testing of metallic and other materials such as oxides, glasses, and fiber-reinforced composites, are included in the course contents.

Learning Outcomes

The Materials Engineering major has the following learning outcomes:

Materials Science and Engineering / 99
• Application of knowledge of mathematics, natural science, and engineering to analysis of materials and other systems
• Learn and work independently
• Practice leadership and teamwork in and across disciplines
• Design of a system, component, or process to meet desired needs
• Effective oral, graphic, and written communication
• Identification, formulation, and solution of engineering problems

Materials Engineering Option

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C.

The Major

Required: Civil and Environmental Engineering 91 (or Mechanical and Aerospace Engineering 101), 108, Electrical and Computer Engineering 100, Materials Science and Engineering 104, 110, 110L, 120, 130, 131, 131L, 132, 143A, 150, 160; one upper-division mathematics course selected from Civil and Environmental Engineering 103, Electrical and Computer Engineering 102, Mathematics 132, Mechanical and Aerospace Engineering 182B, 182C; two laboratory courses (4 units) from Materials Science and Engineering 121L, 141L, 143L, 161L, or up to 2 units of 199; three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Materials Science and Engineering 140); and two major field elective courses (12 units) from Chemical Engineering CM114, Civil and Environmental Engineering 130, 135A, Electrical and Computer Engineering 2, 123A, 123B, Materials Science and Engineering 111, 121, 122, 151, 161, 162, Mechanical and Aerospace Engineering 156A, 166C, plus at least one elective course (4 units) from Chemistry and Biochemistry 30A, 30AL, Electrical and Computer Engineering 131A, Materials Science and Engineering 170, 171, Mathematics 170A, or Statistics 100A.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Electronic Materials Option

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Civil and Environmental Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20; Materials Science and Engineering 10, 90L; Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C.

The Major

Required: Electrical and Computer Engineering 100, 101A, 121B, Materials Science and Engineering 104, 110, 110L, 120 (or Electrical and Computer Engineering 2), 121, 121L, 122, 130, 131, 131L, 132, Mechanic-
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. Three of the nine courses may be upper-division courses.

Ceramics and ceramic processing: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 211, 246D, 298.

Electronic and optical materials: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 221, 222, 223, 298.

Structural materials: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 211, 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 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer 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 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 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 minor 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 multilayer) for electronic and optoelectronic applications.

Course offerings emphasize fundamental issues such as solid-state electronic and optical phenomena, bulk and interface thermodynamics and kinetics, and applications that include growth, processing, and characterization techniques. Active research programs address the relationship between microstructure and nanostructure and electronic/optical properties in these materials systems.

Structural Materials

The structural materials field is designed primarily to provide broad understanding of the relationships between processing, microstructure, and performance of various structural materials, including metals, intermetallics, ceramics, and composite materials. Research programs include material synthesis and processing, ion implantation-induced strengthening and toughening, mechanisms and mechanics of fatigue, fracture and creep, structure/property characterization, nondestructive evaluation, high-temperature stability, and aging of materials.

Facilities

Facilities in the Materials Science and Engineering Department include:

• Ceramic Processing Laboratory
• Glass and Ceramics Research Laboratories
• Mechanical Testing Laboratory
• Metallographic Sample Preparation Laboratory
• Microscopy Laboratories with a transmission electron microscope (100 keV), access to several field-emission transmission electron microscopes (80–300 keV), and a scanning electron microscope equipped with a quantitative chemical/compositional analyzer, a stereo microscope, micro-cameras, and metallurgical microscopes
• Nano-Materials Laboratory
• Nondestructive Testing Laboratory
• Organic Electronic Materials Processing Laboratory
• Semiconductor and Optical Characterization Laboratory
• Thin Film Deposition Laboratory, including molecular beam epitaxy and wafer bonders
• X-Ray Diffraction Laboratory
• X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Facility

Faculty Areas of Thesis Guidance

Professors

Gregory P. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models and characterization, thin film shape memory, nanoscale multiferroics, magnetoelastics and piezoelectric materials

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

Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nano-fabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits, and systems

Bruce S. Dunn, Ph.D. (UCLA, 1974)
Synthesis and characterization of electromechanical materials, energy storage, sol-gel materials and chemistry

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

Mark S. Goorsky, Ph.D. (MIT, 1989)
Electronic materials processing, strain relaxation in epitaxial semiconductors and device structures, high-resolution X-ray diffraction of semiconductors, ceramics, and high-strength alloys

Vijay Gupta, Ph.D. (MIT, 1989)
Experimental mechanics, fracture of engineering solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

Yu Huang, Ph.D. (Harvard, 2003)
Nano-material fabrication and development, bio-nano structures

Professors Emeriti

System scaling technology, advanced packaging and 3D integration, technologies and techniques for memory subsystem integration and neuromorphic computing

Chemical and physical properties of non-metallic archaeological materials; alteration processes in archaeological materials and pigments

Synthesis, characterization, and applications of superhard metals, conducting polymers, thermoelectrics and graphene

Xiaochun Li, Ph.D. (Stanford, 2001)
Soft materials (science-driven manufacturing), super metals by nanoparticles self-dispersion, scalable nanomanufacturing, smart manufacturing, additive manufacturing

Ali Mosteh, Ph.D., NAE (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

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

Dwight C. Streit, Ph.D. (UCLA, 1986)
Properties of electronic materials, characterization techniques, correlation of material and device performance

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

Kang L. Wang, Ph.D. (MIT, 1970)
Nanoscale physics, materials and devices nano-electronics, magnets and photonics, nonlinear interactions of correlated devices and nanosystems

Paul S. Weiss, Ph.D. (UC Berkeley, 1986)
Atomic-scale surface chemistry and physics, molecular devices, nanolithography, biophysics and neuroscience, nanometer-scale electronics and storage, surface interactions, surface motion, dynamic and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes

Processing, characterization, and controlled delivery of biological molecules of biodegradable polymers; design and fabrication of tissue engineering scaffolds and precursor tissue analogs; tissue-material interactions and dental biomaterials

Ya-Hong Xe, Ph.D. (UCLA, 1989)
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, 1968)
Oxidation and sulfidation kinetics and mechanisms, materials compatibility, defect structures, diffusion

Glass science, ceramics, electrical properties of amorphous materials, materials recycling

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

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

Associate Professors

Suneel Kodambaka, Ph.D. (U. Illinois Urbana-Champaign, 2002)
In situ microscopy, surface thermodynamics, kinetics of crystal growth, phase transformations and chemical reactions, thin film physics

Jaime Maran, Ph.D. (U. Berkeley, 2002)
Computational materials modeling and simulation in solid mechanics, irradiation damage, plasticity, phase transformations, thermodynamics and kinetics of alloy systems, algorithm and method development for bridging time and length scales and parallel computing applications

Gaurav N. Sant, Ph.D. (Purdue, 2009)
Development and design of sustainable low-CO₂ footprint materials for infrastructure construction applications

Assistant Professor

Ximin He, Ph.D. (U. Cambridge, England, 2011)
Biologically inspired materials based on stimuli-responsive polymers and micro-/nano-structure fabrication for applications in biomedicine, environment, and energy

Adjunct Associate Professors

Eric P. Bescher, Ph.D. (UCLA, 1987)
Advanced cementitious materials, sol-gel materials, organic/inorganic hybrids

Esther H. Lan, Ph.D. (UCLA, 1994)
Nanobio incorporation of biochemistry into materials science engineering

Sergey Prikhodko, Ph.D. (Kurdyumov Institute for Metal Physics NASU, Ukraine, 1994)
Characterization of materials by means of microscopes and spectroscopes

Lower-Division Courses

10. Freshman Seminar: New Materials. (1) Seminar, one hour, outside study, two hours. Preparation: high school chemistry and physics. Not open to students with credit for course 104. Introduction to basic concepts of materials science and new materials vital to advanced technology. Microstructural analysis of various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. 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.
90L. Physical Measurement in Materials Engineering. (2) Lecture, four hours; outside study, two hours. Various physical measurement methods used in materials science and engineering. Mechan- ical, thermal, electrical, magnetic, and optical techniques. Mr. Kodambaka (WSp).

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 a minimum of 12 units (ex- cluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper-Division Courses

104. Science of Engineering Materials. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20A, 20B, 20L, Physics 1A, 1B. General introduction to different types of materials used in engineering design: metals, ceramics, plastics, and composites; relationship between structure (crystals and microstructure) and properties of technological materials, illustration of their fundamental differences and their applica- tions in engineering. Letter grading. Mr. Dunn (FW,Sp).

M105. Principles of Nanoscience and Nanotechnol- ogy. (4) 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 that emerge in very small systems (typi- cally with feature sizes below few hundred nano- meters) 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. Kodambaka (F).

110. Introduction to Materials Characterization A (Crystal Structure, Nanostructures, and X-Ray Scattering). (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: 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 de- termination; 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. Requisite: course 104. Experimental tech- niques and analysis of materials through X-ray scat- tering techniques; powder method, crystal structure determination, high-resolution X-ray diffraction methods, and special projects. Letter grading. Mr. Goorsky (F).

111. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered C111L. Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisite: course 104. Characterization of microstructure and micro- chemistry of materials; transmission electron micro- copy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, electron microscopy, electron microscopy, emissive and reflective modes; chemical analysis; electron optics of both instruments. Letter grading. Mr. Kodambaka (W).


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 204 (Chemistry 133A). Introduction to electrical, optical, and magnetic proper- ties of solids. Free electron model, introduction to band theory and Schrödinger wave equation. Crystal bonding and defects. Mechanics and characterization of electrical conductivity, optical ab- sorption, magnetic behavior, dielectrical properties, and p-n junctions. Letter grading. Mr. Y. Wang (W).


121L. Materials Science of Semiconductors Laboratory. (2) Lecture, 30 minutes; discussion, 30 min- utes; laboratory, two hours; outside study, three hours. Corequisites: course 120. Experiments con- ducted on materials characterization, including measure- ments of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading. Ms. Huang (W).

122. Principles of Electronic Materials Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 104. Description of basic semiconductors material for device pro- cessing; preparation of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals and dielec- trics. Letter grading. Mr. Goorsky (W).

130. Phase Relations in Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 104. Summary of thermody- namic laws, equilibrium criteria, solution thermody- namics, 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. Requisite: course 130. Diffusion in metals and ionic solids; nucleation; precipitation from solid solution, eutectoid decomposition, design of heat treatment processes of alloys, growth of inter- mediate phases, gas-solid reactions, design of oxida- tion-resistant alloys, recrystallization, and grain growth. Letter grading. Mr. Dunn (W).

131L. Diffusion and Diffusion-Controlled Reac- tions Laboratory. (2) Laboratory, two hours; outside study, four hours. Enforced corequisite: course 131. Design and execution of experiments to study interdiffusion, growth of intermediate phases, recrystallization, and grain growth in metals. Analysis of data. Comparison of results with theory. Letter grading. Mr. Kodambaka (W).


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.


141L. Computer Methods and Instrumentation in Materials Science. (2) Lecture, six hours. Enforced requisite: knowledge of BASIC or C as assembly language. Limited to junior/senior Materials Science and Engineering majors. Interface and control tech- niques, real-time data acquisition, computer 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 131, Mechanical and Aerospace Engineering 101. Plastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocations, fracture, micro- structural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading. Mr. Marian (W).

143L. Mechanical Behavior Laboratory. (2) Labo- ratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Mechanical characteriz- ing mechanical behavior of various materials; plastic and elastic deformation, fracture toughness, fatigue, and creep. Letter grading. Mr. J.-M. Yang (Sp).

150. Introduction to Polymers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, structure crystallinity, and morphology and their ef- fects on physical properties. Glassy polymers, springy polymers, elastomers, adhesives. Fiber forming polymers, polymer processing technology, plastication. Letter grading. Ms. Dunn (F).


160. Introduction to Ceramics and Glasses. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 104, 130. In- troduction to ceramics and glasses being used as im- portant materials of engineering: processing tech- niques, and unique properties. Examples of design and control of properties for certain specific applica- tions in engineering. Letter grading. Mr. Dunn (F).


162. Electronic Ceramics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 104, Physics 1C. Utilization of ceramics in microelec- tronics, fiber optics, thin film transducers, and substrates; design and processing of electronic ceramics and packaging; magnetic ceramics; ferro-
electronic ceramics and electro-optic devices; optical wave guide applications; chemical processing; and laser processing.

Mr. Dunn (Not offered 2018-19)

CM163. Electrochemical Processes. (4) (Same as Chemical Engineering CM114.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 130 (or Mechanical and Aerospace Engineering 102A), Chemical Engineering 102B. Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes. Prerequisite: fundamental approach to analyze electrochemical processes. Specific topics include electrochemical reactions on metal and semiconductor surfaces, electrodeposition, electroreduction, electronic devices, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course CM263. Letter grading.

170. Engaging Elements of Communication: Oral Communication. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Comprehensive oral presentation and communication skills provided by building on strengths of individual personal styles in creation of positive interpersonal relations. Skill set prepares students for different types of academic and professional presentations for wide range of audiences. Learning environment is highly supportive and interactive as it helps students creatively develop and greatly extend effectiveness of their communication and presentation skills. Letter grading.

Mr. Xie (Not offered 2018-19)

CM180. Introduction to Biomaterials. (4) (Same as Bioengineering CM178.) Lecture, three hours; discussion, two hours; outside study, seven hours. Prerequisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials and their application for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and bioactivity. Concurrently scheduled with course CM280. Letter grading.

Mr. Wu (Not offered 2018-19)

188. Special Courses in Materials Science and Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in materials science and engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading. (Not offered 2018-19)

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

199. Directed Research in Materials Science and Engineering. (1 to 4) (Electro) Chemical Engineering C120L, Mechanical and Aerospace Engineering C120L. Undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. Culminating paper or project required. Occasionally offered. May be repeated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (FWSp)

Graduate Courses

200. Principles of Materials Science I. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 110, Lattice dynamics and thermal properties of solids, classical and quantized free electron theory, electrons in a periodic potential, transport in semiconductors, dielectric and magnetic properties of solids. Letter grading.


Ms. He (F)

210. Detection Methods in Science of Materials. (4) Lecture, four hours; recitation, one hour; outside study, seven hours. Requisite: course 110. Theory of diffraction of waves (X-rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long-range 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)

211. Introduction to Materials Characterization B (Electron Microscopy). (4) (Formerly numbered C211L) Lecture, three hours; laboratory, two hours; outside study, seven hours. Requisites: courses 104, 110. Characterization of microstructure and microchemistry of materials; transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; energy-dispersive X-ray spectrometry. Letter grading. Ms. Kakoulli (W)


Ms. Kakoulli (Not offered 2018-19)

M213. Cultural Materials Science I: Analytical Imaging and Document In: Conservation of Materials. (4) (Same as Conservation M215.) Lecture, two hours; laboratory, two hours. Basic and advanced techniques on digital photography, computer-aided recording tools, and scientific imaging to determine and document condition (defects) and technological features of archaeological and ethnographic materials. Development of basic theoretical knowledge on imaging and practical and technical skills on conservation photo-documen- tation, analytical (forensic) photography, and advanced new imaging technologies. Letter grading. Ms. Kakoulli

M213L. Cultural Materials Science Laboratory: Technical Study. (4) (Same as Conservation M221L.) Laboratory, four hours. Requisites: courses M213 (or M216) and one course from Conservation 260 through M264. Corequisites: course C112 or CM212 Conservation 220L. Research laboratory through object-based problem-solving approach in conservation materials science. Experimental techniques, characterization, and analysis of archaeological and ethnographic materials science principles and reverse engineering processes to determine technological features, defects, and products of alteration. Hands-on experience with noninvasive imaging and spectroscopic techniques, and manipulation of samples in the controlled environment of microsamples. Letter grading. Ms. Kakoulli (Sp)

M214. Structure, Properties, and Deterioration of Materials: Rock Art, Wall Paintings, Mosaics. (2) (Same as Conservation M264.) Lecture, three hours. Recommended preparation: basic knowledge of general chemistry and materials science. Introduction to materials and techniques of rock art, wall paintings (including painted surfaces on cement and composite decorative architectural surfaces), and mosaics. Archaeological and ethnographic context, techniques, and materials. Pigments, colorants, and binding media. Chemical, optical, and structural properties. Relationship between materials (including pigment chemistry), structure (crystals, molecular arrangement, and microstructure), and properties explained using basic concepts from physics and chemistry. Intrinsic attributes and aesthetic engineering. Causes, sources, and mechanisms of deterioration (physical, chemical, and biochemical). Letter grading. Ms. Kakoulli (F)


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

222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 120, 139, 137. Thermodynamic growth of nanostructured materials and semiconductor growth and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), heteroepitaxy, implantation, oxidation. Letter grading. Mr. Goorsky (W)

223. Materials Science of Thin Films. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 120, 131, Fabrica-
224. Deposition Technologies and Their Applications. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Examination of physics behind modern thin film deposition technologies, with emphasis on phase transitions in vacuum technology and gas kinetics. Deposition methods used in high-technology applications. Theory and experimental details of physical vapor deposition methods. Self-assembled monolayers. Plasma-enhanced chemical vapor deposition processes. Letter grading. Mr. Xie


226. Si-CMOS Technology: Selected Topics in Materials Science. (4) Lecture, four hours; discussion, three hours; outside study, 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 processing. Emphasis on engineering including advanced material characterization, device science and materials processing. Letter grading. Mr. Goorsky

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Requisite: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture. Fracture mechanics, dislocation mechanics, fracture in real-world 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; discussion, one hour; outside study, seven hours. Requisite: course 143A. Elastic and plastic behavior of crystals, geometry, mechanics, and interaction of dislocations, mechanisms of yielding, work hardening, and other strengthening. Letter grading. Mr. Xie (F, odd years)

246A. Mechanical Properties of Nonmetallic Crystalline Solids. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 160. Materials and environmental factors affecting mechanical properties of nonmetallic single crystal solids, including bonding and structure, atomic-scale defects, microstructural features, residual stresses, temperature, stress state, strain rate, size and surface conditions. Letter grading. Mr. Dunn (W, even years)

246B. Structure and Properties of Glass. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 160. Structure of amorphous solids and glasses. Conditions of glass formation and theories of glass structure. Mechan- cal, electrical, and optical properties of glass and relation to structure. Letter grading. Mr. Dunn (W, even years)

246D. Electronic and Optical Properties of Ceramics. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 160. Principles governing electronic properties of ceramic single crystals and glasses and effects of processing and microstructure on these properties. Electronic conduction, ferroelectricity, and photoluminescence. Magneto-optics and photoacoustic properties, optical absorption and 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; outside study, seven hours. Literature studies of up-to-date subjects in novel materials and their potential applications, including nanoscale materials and biomaterials. Letter grading.

248. Materials and Physics of Solar Cells. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Comprehensive introduction to materials and physics of photovoltaic cell, covering basic physical principles of solar cells, methods of cell fabrication, solar cell 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 cells, thin-film solar cells, and multiple junction solar cells provided to increase student knowledge. Periods of research laboratory included. Letter grading. Ms. Huang (W)

250B. Advanced Composite Materials. (4) Lecture, four hours; outside study, eight hours; Preparation: BS in Materials Science and Engineering. Requisite: course 151. Fabrication methods, structure and properties of composite materials. Fibers, resin-, metal-, and ceramic-matrix composites. Physical, mechanical, and nondestructive characterization techniques. Letter grading. Mr. Y. V. Cao

251. Chemistry of Soft Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven 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; discussion, one hour; outside study, seven hours. Preparation: knowledge of introductory organic chemistry and polymer science. Introduction to electronic organic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers; heavily doped, highly conducting polymers; applications as processable metals in microelectronics, optical, and electro-chemical devices. Synthesis of semiconductor polymers for organic light-emitting diodes, solar cells, thin-film transistors. Introduction to emerging field of organic electronics. Letter grading. Mr. Pei (F)

261. Risk Analysis for Engineers and Scientists. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Topics include definition and fundamental concepts of risk, sociotechnical context of risk assessment and risk management, perception and reality of risk, risk-informed decision-making, domains of application (safety, health, security, economy, and environment), principal methods of risk assessment, including overview of probability and statistics, how to identify risk scenarios, techniques modeling failures of complex systems (e.g., fault tree and event tree analysis), data collection and analysis, model integration and computational algorithmic approaches for risk calculation and identification of risk drivers, simulation approach to risk modeling, uncertainty analysis, examples of risk assessment of engineered systems (e., space and aviation, nuclear power, and transportation) and other applications (risk of medical procedures, financial risk, natural hazards risk). Letter grading. CM230. Electrochemical Processes. (4) Same as Chemical Engineering 2301A. Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 130 (or Mechanical and Aerospace Engineering 105A), Chemical Engineering 102B, and Fundamentals of Chemical Engineering. 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. 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. Marian (F)

271. Electron Structure of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: basic knowledge of quantum mechanics. Recommended requisite: course 200. Introduction to basic physical principles of electronic structure calculations for various types of modern materials. Properties of electrons in atoms and crystals, band structure and optical properties, band mapping and DOS (density of states) using Fermi-Dirac statistics and using it to calculate physical properties such as elastic constants, equilibrium structures, binding energies, vibrational frequencies, electronic band gaps and band structures, properties of defects, surfaces, interfaces, and magnetism. Extensive hands-on experience with modern density-functional theory code. Letter grading. Mr. Marian (W)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Preparation: recommended requisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding of basic principles that determine their behavior. Nanomaterials are now used in devices (as small as 100 nm) from more common microstructured materials. Explanation of new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. 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, optical properties of nanomaterials, 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. Marian (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 methods, and biocompatibility. Concurrently scheduled with course CM180. Letter grading. Mr. Wu (Not offered 2018-19)

282. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Researcher from leading research institutions around the world deliver lectures on advanced research topics in materials science and engineering. Student 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

296. Seminar: Advanced Topics in Materials Science and Engineering. (2) Seminar, two hours; outside study, four hours. 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.
Mechanical and Aerospace Engineering

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H. Pirouz Kavehpour, Ph.D., Vice Chair
Chang-Jin (CJ) Kim, Ph.D., Vice Chair
Ajit K. Mai, Ph.D., Vice Chair

Professors
Mohamed A. Abdou, Ph.D.
Gregory P. Carman, Ph.D.
Yong Chen, Ph.D.
Pei-Yu Chiu, Ph.D.
Vijay K. Dhir, Ph.D.
Jeffrey D. Eldredge, Ph.D.
Timothy S. Fisher, Ph.D. (John P. and Claudia H. Schauerman Endowed Professor of Engineering)
Rajit Gadh, Ph.D.
Naas M. Ghoniem, Ph.D.
James S. Gibson, Ph.D.
Vijay Gupta, Ph.D.
Dennis W. Hong, Ph.D.
Tetsuya Iwasaki, Ph.D.
Y. Sungtaek Ju, Ph.D.
Ann R. Karagozian, Ph.D.
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Chang-Jin (CJ) Kim, Ph.D. (Polvaguen Endowed Professor of Engineering)

J. John Kim, Ph.D. (Rockwell Collins Professor of Engineering)
Adrienne G. Lavine, Ph.D.
Xiaoichun Li, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
Kuo-Nan Liou, Ph.D.
Ajit K. Mai, Ph.D.
Robert T. M’Closkey, Ph.D.
Ali Mosleh, Ph.D., NAE (Evalyn Knight Professor of Engineering)
Jayathi Y. Murthy, Ph.D., Dean
Laurent G. Pilon, Ph.D.
Jacob Rosen, Ph.D.
Jason L. Speyer, Ph.D. (Ronald and Valerie Sugar Endowed Professor of Engineering)
Tsui-Chin Tsao, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti
Oddvar O. Bendiksen, Ph.D.
Ivan Catton, Ph.D. (Research Professor)
Peretz P. Friedmann, Sc.D.
Chih-Ming Ho, Ph.D. (Ben Rich Lockheed Martin Professor Emeritus of Aeronautics)
Robert E. Kelly, Sc.D.
Anthony F. Mills, Ph.D.
D. Lewis Minigori, Ph.D.
Peter A. Monkewitz, Ph.D.
Philip F. O’Brien, M.S.
Lucien A. Schmit, Jr., M.S.
Owen I. Smith, Ph.D.
Richard Stern, Ph.D.
Russell A. Westmann, Ph.D.
Daniel C.H. Yang, Ph.D.

Associate Professors
Robert N. Candler, Ph.D.
Elisa Franco, Ph.D.
Jaima Marian, Ph.D.
Veronica J. Santos, Ph.D.
Kunihiko (Sam) Taira, Ph.D.
Richard E. Wirz, Ph.D.

Assistant Professors
Artur Davayan, Ph.D.
Jonathan B. Hopkins, Ph.D.
Yongjie Hu, Ph.D.
M. Khalid Jawed, Ph.D.
Lihua Jin, Ph.D.
Raymond M. Spearrin, Ph.D.

Lecturers
Raviness C. Amar, Ph.D.
Amiya K. Chatterjee, Ph.D.
Robert J. Kinsey, Ph.D.
Darnian M. Toohay, M.S.

Adjunct Professors
Dan M. Goebel, Ph.D.
Leslie M. Lackman, Ph.D.
Christopher S. Lynch, Ph.D.
Willbur J. Marner, Ph.D.
Neil G. Siegel, Ph.D.

Adjunct Associate 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, microelectromechanical 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

Educational 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 lightweight 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.

Learning Outcomes
The Aerospace Engineering major has the following learning outcomes:
- Application of knowledge of mathematics, science, and engineering
- Function as a productive member of a team that considers multiple aspects of an engineering problem
- Design of a system, component, or process to meet desired needs
- Effective oral and written communication
- Identification, formulation, and solution of engineering problems

Preparation for the Major
Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A; Mechanical and Aerospace Engineering 1, M20 (or Computer Science 31), 82; Physics 1A, 1B, 1C, 4AL, 4BL.

The Major
Required: Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 150A, 157, 166A, 171A; two departmental breadth courses (Electrical and Computer 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; one of the following two tracks (16 units): aeronautics (150B, C150P, 154A, 154S) or space (C150R, 161A, 161B, 161C); three technical breadth courses (12 units) from an approved list available in the Office of Academic and Student Affairs; one capstone design course (Mechanical and Aerospace Engineering 157A); one major field elective course (4 units) from the track not chosen (150B or C150P, C150R or 161A) and one major field elective course (4 units) from Mechanical and Aerospace Engineering 150B, C150P, C150R, 154A, 154S, 161A, 161B, 161C (unless taken as a required course), or from 94, 131A, 133A, 135, 136, C137, CM140, CM141, 150C, C150G, 153A, 155, C156B, 161D, 162A, 166C, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A, M183B, C183C, 184, 185, C186, C187L.

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.

Learning Outcomes
The Mechanical Engineering major has the following learning outcomes:
- Application of knowledge of mathematics, science, and engineering
• Function as a productive member of a team that considers multiple aspects of an engineering problem
• Design of a system, component, or process to meet desired needs
• Effective oral and written communication
• Identification, formulation, and solution of engineering problems

Preparation for the Major

Required: Chemistry and Biochemistry 20A, 20B, 20L; Mathematics 31A, 31B, 32A, 32B, 33A; Mechanical and Aerospace Engineering M20 (or Computer Science 31); 82, 94; Physics 1A, 1B, 1C, 4A, 4B, 4L.

The Major

Required: Electrical and Computer Engineering 110L, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 131A or 133A, 156A, 157, 162A, 171A, 183A (or M183B); two departmental breadth courses (Electrical and Computer Engineering 100 and Materials Science and Engineering 104—if one or both of these courses are taken as part of the technical breadth requirement, students must select a replacement upper-division course or courses from the department—except for Mechanical and Aerospace Engineering 166A—or, by petition, from outside the department); three technical breadth courses (12 units) selected from an approved list available in the Office of Academic and Student Affairs; two capstone design courses (Mechanical and Aerospace Engineering 162D, 162E); and two major field elective courses (8 units) from Mechanical and Aerospace Engineering 131A (unless taken as a required course), 133A (unless taken as a required course), 135, 136, C137, CM140, CM141, 150A, 150B, 150C, C150G, C150P, C150R, 153A, 154S, 155, C156B, 157A, 161A through 161D, 166C, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A (unless taken as a required course), M183B (unless taken as a required course), C183C, 184, 185, C186, C187L.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 21 or https://www.registrar.ucla.edu/Academics/GE-Requirement.

Graduate Study

For information on graduate admission, see Graduate Programs on page 25.

The following introductory information is based on 2018-19 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. 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 Mechanical and Aerospace Engineering offers the Master of Science (M.S.) degree in Manufacturing Engineering, Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Aerospace Engineering, and Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Mechanical Engineering.

All new M.S. and Ph.D. students who are pursuing an M.S. degree in the Mechanical and Aerospace Engineering Department must meet with their advisers in their first term at UCLA. The goal of the meeting is to discuss the students’ plans for satisfying the M.S. degree requirements. Students should obtain an M.S. planning form from the department Student Affairs Office and return it with their advisers’ signature by the end of the first term.

Aerospace Engineering M.S. and Mechanical Engineering M.S.

Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be S98 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 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140, 141L, 150, 160, 161L, 199, Mechanical and Aerospace Engineering 101, 102, 103, 105A, 105D, 107, 188, 194, 199.

Aerospace Engineering

Breadth Requirements. Students are required to take at least three courses from the following four categories: (1) Mechanical and Aerospace Engineering 154A or 154B or 154S, (2) 150B or C150P, (3) 155 or 166A or 169A, (4) 161A or 171A.

Mechanical Engineering

Breadth Requirements. Students are required to take at least three courses from the following five categories: (1) Mechanical and Aerospace Engineering 162A or 169A or 171A, (2) 150A or 150B, (3) 131A or 133A, (4) 156A, (5) 162D or 183A.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three mechanical and aerospace engineering graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students should normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Manufacturing Engineering M.S.

Areas of Study

Consult the department.
Course Requirements

Students may select either the thesis plan or comprehensive examination plan. At least nine courses (and 36 units) are required, of which at least five must be graduate courses. In the thesis plan, seven of the nine must be formal courses, including at least four from the 200 series. The remaining two may be 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor's degree may not be applied toward a graduate degree at UCLA. Choices may be made from the following major areas:

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, 152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M161L, 133A, 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.

Upper-Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering M168, 174, 183A, 184, 185.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering 263A, 263C, 263D, C296A, M297C. Additional Courses. The remaining courses may be taken from other major fields of study in the department or from the following: Architecture and Urban Design 227D, Computer Science 241B, Management 241A, Management-PHD 241A, 241B, Mathematics 120A, 120B.

Comprehensive Examination Plan

The comprehensive examination is required in either written or oral form. A committee of at least three faculty members, with at least two members from within the department, and chaired by the academic adviser, is established to administer the examination. Students may, in consultation with their adviser and the M.S. committee, select one of the following options for the comprehensive examination: (1) take and pass the first part of the Ph.D. written qualifying examination (formerly referred to as the preliminary examination) as the comprehensive examination, (2) conduct a research or design project and submit a final report to the M.S. committee, or (3) take and pass three comprehensive examination questions offered in association with three graduate courses. Contact the department Student Affairs Office for more information.

Thesis Plan

The thesis must describe some original piece of research that has been done under the supervision of the thesis committee. Students would normally start to plan the thesis at least one year before the award of the M.S. degree is expected. There is no examination under the thesis plan.

Aerospace Engineering Ph.D. and Mechanical Engineering Ph.D.

Major Fields or Subdisciplines

Design, robotics, and manufacturing (mechanical engineering only); fluid mechanics; nanoelectromechanical/microelectromechanical systems (NEMS/MEMS); structural and solid mechanics; systems and control; thermal science and engineering.

Ph.D. students may propose ad hoc major fields, which must differ substantially from established major fields and satisfy one of the following two conditions: (1) the field is interdisciplinary in nature or (2) the field represents an important research area for which there is no established major field in the department (condition 2 most often applies to recently evolving research areas or to areas for which there are too few faculty members to maintain an established major field).

Students in an ad hoc major field must be sponsored by at least three faculty members, at least two of whom must be from the department.

Course Requirements

The basic program of study for the Ph.D. degree is built around major and minor fields. The established major fields are listed above, and a detailed syllabus describing each Ph.D. major field can be obtained from the Student Affairs Office.

The program of study for the Ph.D. requires students to perform original research leading to a doctoral dissertation and to master a body of knowledge that encompasses material from their major field and breadth material from outside the major field. The body of knowledge should include (1) six major field courses, at least four of which must be graduate courses, (2) one minor field, (3) any three additional courses, at least two of which must be graduate courses, that enhance the study of the major or minor field.

The major field syllabus advises students as to which courses contain the required knowledge, and students usually prepare for the written qualifying examination (formerly referred to as the preliminary examination) by taking these courses. However, students can acquire such knowledge by taking similar courses at other universities or even by self-study.

The minor field embraces a body of knowledge equivalent to three courses, at least two of which must be graduate courses. Minor fields are often subsets of major fields, and minor field requirements are then described in the syllabus of the appropriate major field. Established minor fields with no corresponding major field can also be used, such as applied mathematics and applied plasma physics and fusion engineering. Also, an ad hoc field can be used in exceptional circumstances, such as when certain knowledge is desirable for a program of study that is not available in established minor fields. Grades of B– or better, with a grade-point average of at least 3.33 in all courses included in the minor field, and the three additional courses mentioned above are required. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only).

Written and Oral Qualifying Examinations

After mastering the body of knowledge defined in the major field, students take a written qualifying (preliminary) examination covering this knowledge. Students must have been formally admitted to the Ph.D. program or admitted subject to completion of the M.S. degree by the end of the term following the term in which the examination is given. The examination must be taken within the first two calendar years from the time of admission into the Ph.D. program. Students must be registered during the term in which the examination is given and be in good academic standing (minimum GPA of 3.25). The student's major field proposal must be completed prior to taking the examination. Students may not take an examination more than twice. Students in an ad hoc major field must pass a written qualifying examination that is approximately equivalent in scope, length, and level to the written qualifying examination for an established major field. After passing the written qualifying examination, students take the University Oral Qualifying Examination within four calendar years.
from the time of admission into the Ph.D. program. The nature and content of the examination are at the discretion of the doctoral committee but include a review of the dissertation prospectus and may include a broad inquiry into the student's preparation for research.

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

Fields of Study

Design, Robotics, and Manufacturing

The program is developed around an integrated approach to design, robotics, and manufacturing. It includes research on 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.

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, supersonic flows, microscale and nanoscale flow phenomena, aeracoustics, biofluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microrheology, biofluid mechanics, supersonic, reactive flow, fluid stability, turbulence, and experimental methods.

Nanoelectromechanical/Microelectromechanical Systems

The nanoelectromechanical/microelectromechanical systems (NEMS/MEEMS) 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/mechanical system 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 aerelasticity, biomechanics 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 and Computer 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.

Thermal Science and Engineering

The thermal science and engineering 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 microscale and nanoscale thermosciences, energy, bioMEMS/NEMS, and microfabrication/nanofabrication.

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.

Centers, Facilities, and Laboratories

The Mechanical and Aerospace Engineering Department has a number of experimental centers, facilities, and laboratories at which both fundamental and applied research is being conducted. More information is at https://www.mae.ucla.edu.

Active Materials Laboratory

Gregory P. Carman, Director

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 in the lab. All of the load frames are equipped with thermal chambers, sledenoids, and electrical power supplies.

Autonomous Vehicle Systems Instrumentation Laboratory

Jason L. Speyer, Director

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. 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 modern communication.
Beam Control Laboratory
James S. Gibson, Director
The Beam Control Laboratory involves students, faculty, and postdoctoral scholars to develop novel methods for laser-beam control in applications including directed energy systems and laser communications. Algorithms developed at UCLA for adaptive and optimal control and filtering, as well as system identification, are being used in adaptive optics and beam steering. UCLA high-bandwidth controllers correct both higher-order wavefront errors and tilt jitter to levels not achievable by classical beam control methods.

Biomechatronics Laboratory
Veronica J. Santos, Director
The Biomechatronics Laboratory is dedicated to improving quality of life by enhancing the functionality of artificial hands and their control in human-machine systems. The research is advancing the design and control of human-machine systems as well as autonomous robotic systems. Current research projects involve human biomechanics, tactile sensing, control of robotic systems, and machine learning.

Bionics Laboratory
Jacob Rosen, Director
The Bionics Laboratory performs research at the interface between robotics, biological systems, and medicine. Primary research fields are medical robotics and biorobotics including surgical robotics, and wearable robotics as they apply to human motor control, neural control, human- and brain-machine interfaces, motor control (stroke) rehabilitation, brain plasticity, haptics, virtual reality, tele-operation, and biomechanics (full-body kinematics and dynamics, and soft/hard tissues biomechanics).

Boiling Heat Transfer Laboratory
Vijay K. Dhir, Director
The Boiling Heat Transfer Laboratory performs experimental and computational studies of phase-change phenomena. It is equipped with various flow loops, state-of-the-art data acquisition systems, holography, high-speed imaging systems, and a gamma densitometer.

Center for Advanced Multifunctional Materials and Systems (CAMMS)
Christopher S. Lynch, Director
CAMMS is involved in all aspects of multifunctional (smart) materials characterization, modeling, and applications. Materials are characterized under combined mechanical, thermal, electrical, and magnetic loading. Constitutive laws are developed that govern domain switching and phase transformations. Component-level applications include miniature solid-state piezoelectric pumps; morphing piezocomposite actuators; and nanoscale magneto-electric memory, antenna, and motors. Systems-level applications (team projects) include controlled optics for deep-space observing satellites, ultra-low-frequency magneto-mechanical antennas, morphing aircraft structures, and next-generation computer memory.

Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS)
Gregory P. Carman, Director
The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) is a multi-institutional engineering research center (ERC) focused on research, technology translation, and education associated with magnetism on the small scale. The TANMS vision is to develop a fundamentally new approach that couples electricity to magnetism using engineered nanoscale multiferroic elements, to enable increased energy efficiency, reduced physical size, and increased power output in consumer electronics. This new approach overcomes scaling limitations present Oersted’s magnetism control discovery of 1820. TANMS goals are to translate its research discoveries to industry, while seamlessly integrating a cradle-to-career education philosophy involving its students and future engineers in unique research and entrepreneurial experiences.

Chen Research Group
Yong Chen, Director

Collaborative Center for Aerospace Sciences (CCAS)
Ann R. Karagozian, Director
The Collaborative Center for Aerospace Sciences (CCAS) is a multi-/trans-disciplinary research center focused on fundamental and applied basic studies relevant to aerospace systems. Research projects that broadly span the computational and experimental arenas are conducted at UCLA and at Air Force Research Laboratory (AFRL/RQ) at Edwards Air Force Base northeast of campus. UCLA faculty, students, and postdoctoral researchers collaborate with AFRL scientists and engineers on high-impact problems to advance U.S. capabilities in aerospace systems.

Complex Fluids and Interfacial Physics Laboratory
H. Pirouz Kavehpour, Director
The Complex Fluids and Interfacial Physics Laboratory is multidisciplinary, with areas of research ranging from rheology of biofluids to energy storage. The group is directed towards development of fundamental engineering and scientific knowledge.

Cybernetic Control Laboratory
Tetsuya Iwasaki, Director
The Cybernetic Control Laboratory (CyCLab) aims to develop biologically inspired control theories for rhythmic movements and dynamic pattern formation with applications to robotic vehicles, devices for human assist, and rehabilitation.

Design and Manufacturing Laboratory
The Design and Manufacturing Laboratory offers an environment for synergistic integration of design and manufacturing. Available equipment includes four CNC machines, two rapid-prototyping systems, coordinate measuring, X-ray radiography, robots with vision systems, audiovisual equipment, and a distributed network of more than 30 workstations.

Energy and Propulsion Research Laboratory
Ann R. Karagozian, Director
The Energy and Propulsion Research Laboratory involves the application of modern diagnostic methods and computational tools to the development of improved combustion, propulsion, and fluid flow systems. Research includes aspects of fluid mechanics, chemistry, optics, and numerical methods, as well as thermodynamics and heat transfer.

Energy Innovation Laboratory
Richard E. Wirz, Director
The Energy Innovation Laboratory investigates high-impact renewable energy science and technology. Its current work primarily focuses on large-scale thermal energy storage for grid-scale applications and advanced wind energy capture.
Flexible Research Group
Jonathan B. Hopkins, Director
The Flexible Research Group is dedicated to the design and fabrication of flexible structures, mechanisms, and materials that achieve extraordinary capabilities. The laboratory is equipped with state-of-the-art synthesis tools, optimization software, and a number of commercial and custom-developed additive fabrication technologies for fabricating complex flexible structures at the macro- to nano-scale.

Fusion Science and Technology Center
Mohamed A. Abdou, Director
The Fusion Science and Technology Center includes experimental facilities for conducting research in fusion science and engineering, and multiple scientific disciplines in thermofluids, thermomechanics, heat/mass transfer, and materials interactions. The center includes experimental facilities for liquid metal magnetohydrodynamic fluid flow, thick and thin liquid metal systems exposed to intense particle and heat flux loads, and metallic and ceramic material thermomechanics.

Ho Systems Laboratory—Personalized Medicine
Chih-Ming Ho, Director
The Ho Systems Laboratory—Personalized Medicine researches phenotypic personalized medicine (PPM). It has discovered that drug-dose inputs are correlated with phenotypic outputs with a parabolic response surface (PRS). With a few calibration tests to determine the coefficients of its quadratic governing algebraic equation, PRS dictates the composition and ratio of a globally optimized drug combination. Based on the PRS platform, phenotypic personalized medicine (PPM) can realize unprecedented adaptability to identify the optimized drug combination for a specific patient. PRS is an indication-agnostic and mechanism-free platform technology, which has been successfully demonstrated in about 30 diseases.

Hu Research Laboratory (H-Lab)
Yongjie Hu, Director
The H-Lab research group is focused on understanding and engineering nanoscale transport phenomena and nanomaterials for wide applications including energy conversion, storage, and thermal management. The lab uses a variety of experimental and theoretical techniques to investigate nanoscale transport processes, with a particular emphasis on design and chemical synthesis of advanced materials, ultrafast optical spectroscopy, pulsed electronics, and thermal spectral mapping techniques.

Hypersonics and Computational Aerodynamics Group
Xiaolin Zhong, Director
The Hypersonics and Computational Aerodynamics Group primarily focuses on fundamental physics-based research of hypersonic flows using advanced numerical tools; and application of discovered fundamental knowledge to real-world aerospace systems, such as development of hypersonic planes and space vehicles. Its main research areas are computational fluid dynamics (CFD), hypersonic flows, instability and transition of hypersonic boundary layers, interaction of strong shocks and turbulence, and numerical simulation of wave energy harvesting.

Laser Spectroscopy and Gas Dynamics Laboratory
Raymond M. Spearin, Director
The Laser Spectroscopy and Gas Dynamics Laboratory conducts research driven by applications in propulsion and energy, with extensions to health and environment. Lab activities are united by a core focus in experimental thermofluids and applied spectroscopy. Projects commonly span fundamental spectroscopy science to design and deployment of prototype sensors to investigate dynamic flow-fields.

Materials Degradation Characterization Laboratory
Ajit K. Mal, Director
The Materials Degradation Characterization Laboratory is used for 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 research on fracture mechanics and ultrasonic non-destructive evaluation.

Materials in Extreme Environments Laboratory (MATRIX)
Nasr M. Ghoniem, Director
The Materials in Extreme Environments (MATRIX) Laboratory seeks answers to two fundamental questions: What are the physical phenomena that control the mechanical properties of engineering materials operating in extreme environmental conditions; and knowing such behavior, can we design engineering materials to be more resilient.

M’Closkey Laboratory
Robert T. M’Closkey, Director
The M’Closkey Laboratory develops miniature, high-performance angular-rate sensors called vibratory gyroscopes. A separate long-term project seeks to understand the mixing dynamics of a jet injected into a crossflow.

Mechanics of Soft Materials Laboratory
Lihua Jin, Director
The Mechanics of Soft Materials Laboratory investigates the fundamental physics and mechanics of soft materials, such as their constitutive relation, nonlinear deformation, instability, and fracture. The lab also strives to develop new materials, structures, and functions for soft robotics and stretchable electronics.

Mechatronics and Controls Laboratory
Tsu-Chin Tsao, Director
The Mechatronics and Controls Laboratory conducts research in theory and innovation in dynamic systems, controls, mechatronics, and robotics. It creates high-performance systems with novel sensors, actuators, and real-time digital signal processing and embedded control. Applications include precision motion and vibration control, manufacturing equipment and processes, medical devices, and robots.

Micro- and Nano-Manufacturing Laboratory
Chang-Jin (CJ) Kim, Director
The Micro- and Nano-Manufacturing Laboratory is equipped with a fume hood, clean air bench, optical table, DI water generator, plating setup, probe station, various microscopes, test and measurement systems, and CAD programs for mask layout. It is used for micromachining and MEMS research, and complements the UCLA Samuel Nanoelectronics Research Facility.

Modeling of Complex Thermal Systems Laboratory
Adrienne G. Lavine, Director
The Modeling of Complex Thermal Systems Laboratory addresses a variety of systems in which heat transfer plays an important role.
Thermal aspects of these systems are coupled with other physical phenomena such as mechanical or electrical behavior. Modeling tools range from analytical to custom computer codes to commercial software.

**Morrin-Gier-Martinelli Heat Transfer Memorial Laboratory**

Laurent G. Pilon, Director

The Morrin-Gier-Martinelli Heat Transfer Memorial Laboratory is shared between professors Catton and Pilon. It is used for investigating single- and two-phase convective heat transfer in energy applications, various aspects of radiation transfer in biological systems, and material synthesis and characterization. It is equipped with optical tables, lasers, FTIR, photomultiplier tubes, monochromators, nanosecond pulse diodes, lock-in amplifiers, spectrophotometers, light guides, fiber optics, lenses, and polarizers. It also has various flow loops, a wind tunnel, and a particle image velocimetry (PIV) system. For material synthesis, the lab is equipped with two high-temperature furnaces, a spin coater, a dip-coating system, and UV curing lamps. The lab can perform optical, thermal, and electrical materials characterization using a guarded hot plate thermal conductivity analyzer, a 3-omega method system for thin film thermal conductivity, a normal-normal reflection probe, and an in-house electrical system for measuring dielectric constant and the q-V curve of ferroelectric materials.

**Multiscale Thermosciences Laboratory (MTSL)**

Y. Sungtaek Ju, Director

The Multiscale Thermosciences Laboratory (MTSL) is focused on heat and mass transfer phenomena at the nano- to macro-scales. A wide variety of applications are explored, including novel materials and devices for energy conversion; combined cooling, heating, and power generation; thermal management of electronics and buildings; energy-water nexus; and biomedical MEMS/NEMS devices.

**Nanoscale Transport Research Group**

Timothy S. Fisher, Director

The Nanoscale Transport Research Group works on a broad range of problems, primarily involving transport processes by electrons, phonons, photons, and fluids. It seeks to solve problems with high importance to applications in energy transport, conversion, and storage, that are relevant to major industrial segments (aerospace, micro/nanoelectronics, and sensors). The lab solves these problems through a holistic, balanced approach that spans nanomaterial synthesis, basic material characterization and modeling, and functional characterization and simulation. The group includes the Center for Integrated Thermal Management of Aerospace Vehicles (CITMAV), which develops new solutions to highly transient transport problems that occur in aerospace applications.

**Optofluidics Systems Laboratory**

Pei-Yu Chiou, Director

The Optofluidics Systems Laboratory develops heterogeneously integrated functional devices and systems for biomedical applications. Research areas include integrated photonics and fluidics devices; 3D micro- and nano-manufacturing technologies; and flexible mechanical, photonics, and electronics systems.

**Pilon Research Group**

Laurent G. Pilon, Director

The Pilon Research Group researches photobiological fuel production, mesoporous materials, electrochemical capacitors, waste heat energy harvesting, foams/microfoams, biomedical optics, and energy efficiency.

**Plasma and Beam Assisted Manufacturing Laboratory**

Richard E. Wirz, Director

The Plasma and Beam Assisted Manufacturing Laboratory is an experimental facility for 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 DC supplies (400kw), vacuum chambers, and large electromagnets. Current research is focused on ceramic coatings and nanoparticle clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

**Plasma and Space Propulsion Laboratory**

Rajit Gadh, Director

The Smart Grid Energy Research Center (SMERC) performs research; creates innovations; and demonstrates advanced Internet-of-things, sense-and-control technologies, and data-enabled machine learning to enable development of the next-generation electric utility grid—the smart grid. SMERC also provides thought leadership through its ESmart Consortium between utilities, government, policy makers, technology providers, electric vehicle manufacturers, energy technology companies, Department of
Energy research labs, and universities, so as to collectively work on envisioning, planning, and executing the smart grid of the future. That grid will allow for integration of renewable energy sources. It will also reduce losses; improve efficiencies; increase grid flexibility; reduce power outages; allow for competitive electricity pricing; allow for integration of electric and autonomous vehicles; and overall become more responsive to market, consumer, and societal needs. SMERC is currently working electric vehicle integration (G2V and V2G), automated demand response (ADR), microgrids, distributed energy resources, renewable integration, battery energy storage integration, and autonomous vehicle infrastructure.

Simulations of Flow Physics and Acoustics Laboratory (SOFiA)
Jeffrey D. Eldredge, Director
The Simulations of Flow Physics and Acoustics (SOFiA) Laboratory explores a wide variety of phenomena that occur in fluid flows in nature and technology. It investigates low-order modeling of unsteady aerodynamics of agile, bio-inspired, micro-air vehicles; micro-particle manipulation by viscous streaming; the fluid dynamics of biological and biologically-inspired locomotion; interactions of fluid flows with flexible surfaces; transitional and turbulent hypersonic boundary layer flows; vortex estimation techniques for autonomous control of flight; and new computational tools for simulation of biomedical flows.

Thermochemical Energy Storage Laboratory
Adrienne G. Lavine, Director
The Thermochemical Energy Storage Laboratory is focused on use of reversible chemical reactions to store energy for renewable energy applications. The current focus is on ammonia synthesis for supercritical steam generation in a concentrating solar power plant. The ammonia synthesis reactor testing platform consists of three subsystems (disassociation, synthesis, and steam generation) that work in unison to create a closed-loop synthesis gas generator that can operate for an indefinite period of time.

Thin Films, Interfaces, Composites, Characterization Laboratory
Vijay Gupta, Director
The Thin Films, Interfaces, Composites, Characterization Laboratory includes a Nd:YAG laser of 1 Joule capacity with 3 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, and polishing and imaging equipment for microstructural characterization, for measurement and control study of thin film interface strength.

Turbulence Research Group
J. John Kim, Director
The Turbulence Research Group is primarily focused on the study of turbulence and stability. It has a long history of studying incompressible flow, and has recently begun studying compressible flow problems. All its work is carried out numerically with computational fluid dynamic (CFD) codes, which are written in-house. Its current research interests include real gas effects on compressible turbulent boundary-layer flow, drag reduction through the use of superhydrophobic surfaces on incompressible turbulent boundary-layer flow, and the effects of distributed roughness on compressible turbulent boundary-layer flows.

Faculty Areas of Thesis Guidance

Professors
Mohamed A. Abdou, Ph.D. (U. Wisconsin, 1972)
Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermal-mechanics; thermal hydraulics; fluid dynamics, heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-material interactions; blankets and high heat flux components; experiments, modeling and analysis

Gregory R. Carman, Ph.D. (Virginia Tech, 1991)
Electromagnetoelasticity models including micromagnetics, elastodynamics, and Maxwell coupled solutions. Characterization of piezo-electric ceramics, magnetostrictive shape memory alloys, and multiferroic materials.

Yong Chen, Ph.D. (UC Berkeley, 1996)
Nanoscale science and engineering, micro- and nanofabrication, self-assembly phenomena, microscale and nanoscale electronic, mechanical, optical, biological, and sensing devices, circuits and systems

Pei-Yu Chiou, Ph.D. (UC Berkeley, 2005)
BioMEMS, biophotonics, electrokinetics, optical manipulation, optoelectronic devices

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 cooling

Jeffrey D. Eldredge, Ph.D. (Caltech, 2002)
Numerical simulations of fluid dynamics, bio-inspired locomotion in fluids, transition and turbulence in high-speed flows, aerodynamically generated sound, vorticity-based numerical methods, simulations of biomedical flows

Timothy S. Fisher, Ph.D. (Cornell, 1998)
Heat and mass transfer, interfacial transfer, nanomaterial synthesis, nano/micro-device fabrication, non-equilibrium thermodynamics, subcontinuum modeling and measurements of heat and charge transport, electrochemical and thermal energy storage, mechanics and transport in granular materials and porous media, plasma science and technology, aerospace thermal systems

Smart grid, electric vehicle and grid integration, microgrid, distributed energy resource, solar and renewable-grid integration, demand response, autonomous electric vehicle, machine learning from transportation data, radio frequency identification (RFID), Internet of things

Nasr M. Ghoniem, Ph.D. (U. Wisconsin, 1977)
Mechanics of materials in severe environments (nuclear, aerospace, transportation); radiation interaction with materials (e.g., laser, ions, plasma, electrons, and neutrons); multiscale modeling; physics and mechanics of material defects; fusion energy; materials for space propulsion

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 engineer- ing solids, mechanics of thin film and interfaces, failure mechanisms and characterization of composite materials, ice mechanics

Dennis W. Hong, Ph.D. (Purdue, 2002)
Analysis and visualization of contact force solution space for multilimbed 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 and mass transfer, energy, energy-water nexus, MEMS and nanotechnology

Alan R. Karagozian, Ph.D. (Caltech, 1982)
Fluid mechanics and combustion with applications to air breathing, rocket propulsion, and energy-generation systems, focusing on control of instabilities improved efficiency, and reduced emissions

H. Pirouz Kavehpour, Ph.D. (MIT, 2003)
Microscale fluid mechanics, transport phenomena in biological systems, biofluids, coating flows and physics of contact line phenomena, complex fluids, non-isothermal flows, energy systems and energy storage

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

J. John Kim, Ph.D. (Stanford, 1978)
Numerical simulation of turbulent and transitional flows, physics and control of turbulent flows, application of modern control theories to flow control

Adrienne Lavine, Ph.D. (UC Berkeley, 1984)
Heat transfer: thermomechanical behavior of shape memory alloys, thermal aspects of manufacturing processes, natural and mixed convection

Xiaochun Li, Ph.D. (Stanford, 2001)
Embedded sensors in layered 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

Ajit K. Mal, Ph.D. (Calcutta U., India, 1964)
Mechanics of solids, composite materials, wave propagation, nondestructive evaluation, structural health monitoring

Robert T. M’Closkey, Ph.D. (Cornell, 1995)
Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation
Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974)
Ivan Catton, Ph.D. (UCLA, 1966)
Ali Mosleh, Ph.D., NAE (UCLA, 1981)
Xiaolin Zhong, Ph.D. (Stanford, 1991)
Tsu-Chin Tsao, Ph.D. (UC Berkeley, 1988)
Jason L. Speyer, Ph.D. (Harvard, 1968)
Jacob Rosen, Ph.D. (Tel Aviv U., Israel, 1997)
Laurent G. Pilon, Ph.D. (Purdue, 2002)
Lucien A. Schmit, Jr., M.S. (MIT, 1960)
Structural mechanics, optimization, automated design methods for structural systems and components, application of finite element analysis techniques and mathematical programming algorithms in structural design, analysis and synthesis methods for fiber composite structural components
Owen I. Smith, Ph.D. (UC Berkeley, 1977)
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition
Richard Stern, Ph.D. (UCLA, 1964)
Experimention in noise control, physical acoustics, engineering acoustics, medical acoustics
Russell A. Westmann, Ph.D. (U.C. Berkeley, 1962)
Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems
Daniel C.H. Yang, Ph.D. (Rutgers, 1982)
Robotics and mechanisms; CAD/CAM systems, computer-controlled machines
Robert N. Candler, Ph.D. (Stanford, 2006)
MEMS and nanoscale devices, fundamental limitations of sensors, packaging, biological and chemical sensing
Elisa Franco, Ph.D. (U. Trieste, Italy, 2007; Caltech, 2011)
Convergence of structural biology, dynamics, and controls using specialized biomolecular frameworks
Jaime Marian, Ph.D. (UC Berkeley, 2002)
Computational materials modeling and simulation in solid mechanics, irradiation damage, plasticity, phase transitions, thermodynamics and kinetics of alloy systems, algorithm and method development for bridging time and length scales and parallel computing applications
Veronica J. Santos, Ph.D. (Cornell, 2007)
Grasp and manipulation, hand biomechanics, haptics, human-machine systems, machine learning, machine perception, thermal control of movement, prosthetics, robotics, stochastic modeling, machine learning
Kunihiko (Sam) Taira, Ph.D. (Caltech, 2008)
Development of computational fluid dynamics that incorporate unsteady aerodynamics, flow control, and network theory
Richard E. Witz, Ph.D. (Caltech, 2005)
Electric propulsion (ion, Hall, electrosprays, cathodes); micro-electro propulsion; partially ionized plasma discharges; miniature plasma devices; spacecraft/space mission design; wind energy; solar thermal energy; thermal energy storage
Artur Davoyan, Ph.D. (Australian National U., 2011)
Devising and development of new approaches for space propulsion and power using unique nanomaterials
Jonathan B. Hopkins, Ph.D. (MIT, 2010)
Design and manufacturing of microstructural architectures, flexure systems, and compliant mechanisms; screw theory kinematics; precision machined designs; novel MEMS and nano-fabrication processes; MEMS
Yongjie Hu, Ph.D. (Harvard, 2011)
Heat transfer and electron transport in nanostructures; interfaces and packaging; thermal, electronic, and thermoelectric devices and systems; energy conversion, storage, and thermal management; ultrafast optical spectroscopy and high-frequency electronics; nanomaterials design, processing, and manufacturing
M. Khalid Jawed, Ph.D. (MIT, 2016)
Data-driven approach to modeling the mechanics of structures and fluid-structure interaction using robotics, automation, computation, and machine learning
liu Jia, Ph.D. (Harvard, 2014)
Mechanics of soft materials; continuum mechanics and applications in technologies: additive manufacturing, soft robotics and stretchable electronics, nanomechanics, and multiscalar modeling
Raymond M. Spearrin, Ph.D. (Stanford, 2015)
Spectroscopy and gas dynamics, advanced optical sensors including laser absorption and fluorescence with experimental application to propulsion, energy systems and other reacting flow fields

Lecturers

Ravesh C. Amar, Ph.D. (UCLA, 1974)
Heat transfer and thermal science

Amiya K. Chatterjee, Ph.D. (UCLA, 1976)
Elastic wave propagation and penetration dynamics

Modeling, simulation, and analysis of spacecraft dynamics and pointing control systems; non-linear dynamics of spinning bodies; concurrent engineering methods for space mission conceptual design

Dannick M. Toch发言, Ph.D. (MIT, 2004)
Guidance, navigation, and control for autonomous aircraft, launch vehicles, and missile systems, adaptive control techniques, automatic control re-allocation for aircraft and re-entry vehicles

Adjunct Professors

Dan M. Goeble, Ph.D. (UCLA, 1981)
Hollow cathodes, magnetic/multiple ion sources for neutral beam injection

Lester M. Lackman, Ph.D. (UC Berkeley, 1967)
Structural analysis and design, composite structures, engineering management

Christopher S. Lynch, Ph.D. (UC Santa Barbara, 1992)
Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensor and actuator applications, fracture mechanics and failure analysis

Wilbur J. Marner, Ph.D. (U. South Carolina, 1969)
Thermal sciences, system design

Neil G. Siegel, Ph.D. (USC, 2011)
Organizing complex projects around critical skills and mitigation of risks arising from system dynamic behavior

Adjunct Associate Professor

Abdon E. Sepulveda, Ph.D. (UCLA, 1990)
Optimal placement of actuators and sensors in control augmented structural optimization

Lower-Division Courses

1. Undergraduate Seminar. (1) Seminar, one hour; outside study, two hours. Introduction by faculty members and industry lecturers to mechanical and aerospace engineering disciplines through current and emerging applications in aerospace, medical instrumentation, automotive, entertainment, energy, and manufacturing industries. P/NP grading

Mr. Mal (F)


Ms. Lavine (Not offered 2018-19)
116 / Mechanical and Aerospace Engineering

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


Mr. Eldredge, Mr. Taciorglu (F,W,Sp)


Mr. Mal (F,W,Sp)

94. Introduction to Computer-Aided Design and Drafting. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Fundamentals of computer-aided design and drafting. Students use one or more online computer systems to design and display various objects. Letter grading.

Mr. Gadg, Mr. Li (F,W,Sp)

99. Student Research Program. (1 to 2) Tutorial (supervised research or other scholarly work), three hours per week per unit. Entry-level research for lower-division students guided by faculty members. 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.

Mr. Gadg, Ms. Karagozian (F,W,Sp)

Upper-Division Courses


102. Dynamics of Particles and Rigid Bodies. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 101, Mathematics 33A, Physics 1A. Fundamental concepts of Newtonian mechanics. Kinematics and kinetics of particles and rigid bodies in two and three dimen- sions. Impulse-momentum and work-energy relationships. Applications. Letter grading.

Mr. Kavehpour, Mr. J. Kim (F,W,Sp)

105A. Introduction to Engineering Thermody- namics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Chemistry 20B, Mathematics 32B. Phenomenological ther- momodynamics. Concepts of equilium, temperature, and reversibility. First and second law of energy and second law and concept of entropy. Equations of state and thermodynamic properities. Engineering appli- cations of these principles in analysis and design of closed and open systems. Letter grading.

Mr. Pilon (F,W,Sp)


Mr. Ju, Ms. Lavine (F)

107. Introduction to Modeling and Analysis of Dy- namic Systems. (4) Lecture, four hours; discussion, one hour; laboratory, two hours; outside study, five hours. Enforced requisites: courses M20 or (Computer Science 31), 82, Electrical Engineering 100. In- troduction to modeling of dynamical systems with examples of mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency re- sponse, matrix transfer function, and Laplace transform re- sponse analysis, and numerical solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response. Block diagram representation and response of interconnections of systems. Hands-on experiments reinforce lecture material. Letter grading.

Mr. M’Closkey, Mr. Tsao (F,W,Sp)


Ms. Lavine (F)

133A. Engineering Thermodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 82, 103, 105A. Applications of thermodynamic principles to engineering processes. Energy conversion systems. Rankine cycle and other cycles, refrigeration, psychrometry, reactive and non- reactive fluid flow systems. Elements of thermody- namics design. Letter grading.

Mr. Abdou (F)

135. Fundamentals of Nuclear Science and Engi- neering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 82, Chemistry 20A. Review of nuclear physics, radio- activity and decay, and radiation interaction with matter. Nuclear fission and fusion processes and mass defect, chain reactions, criticality, neutron diffu- sion and multiplication, heat transfer issues, and ap- plications. Introduction to nuclear power plants for commercial electricity production, space power, spacecraft propulsion, nuclear fusion, and nuclear science for medical uses. Letter grading.

Mr. Abdou (F)

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: 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 conser- vation, and water pollution, global warming. Letter grading.

Mr. Pilon (F)

C137. Design and Analysis of Smart Grids. (4) Lecture, four hours; discussion, outside study, eight hours. De- mand response; transactive/price-based load con- trol; home-area energy profile; advanced metering infrastructure; renewable energy in- tegration; solar and wind generation intermittency and correction; microgrids; grid stability; energy storage and electric vehicle charging; distribution and transmission grids; consumer-centric technologies; sensors, communications, and com- puting; wireless, wireline, and powerline communica- tions for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational awareness, phaser measurements; analytical methods and tools for planning and control. Concurrently scheduled with course C237. Letter grading.

Mr. Gadg (F)

CM140. Introduction to Biomechanics. (4) Same as Bioengineering CM140.) Lecture, four hours; dis- cussion, two hours; outside study, six hours. Requi- sites: courses 101, 102, and 150A. Introduction to the interactions of mechanical systems and the structures that govern how they function biologically. Re- view and application of continuum mechanics and dynamics to problems of function. Engineering appli- cations to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power genera- tion. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading.

Ms. Karagozian (F)


Mr. Gupta (W)


Mr. Eldredge, Ms. Karagozian (F,W)


Mr. Zhong (Sp)


Ms. Karagozian (W)

C150G. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requi- site: course 103. Mechanics of aquatic locomotion; insect and bird flight aerodynamics; fluid flow in circulatory system; rheology of blood; transport in mi- crocirculation; role of fluid dynamics in arterial dis- eases. Concurrently scheduled with course C250G. Letter grading.

Mr. Eldredge (Not offered 2018-19)

C150P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 105A, 105A. Thermody- namic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concur- rently scheduled with course C250P. Letter grading.

Ms. Karagozian (F)
153A. Engineering Acoustics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for junior/senior engineering majors. Fundamental course in acoustics; propagation of sound; sources of sound. Design of field measurements. Estimation of jet and blade noise with design aspects. Letter grading. Mr. Eldredge (Not offered 2018-19)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 154B. Class-
154B. Design of Aerospace Structures. (4) Lecture, four hours; outside study, eight hours. Requi-
sites: courses 154A, 166A. Design of aircraft, heli-
copters, and related structures. Applied analysis of loads, internal stresses. Applied theory of thin-walled structures. Material selection, design using com-
posite materials. Design for fatigue prevention and structural optimization. Field trips to aerospace com-
panies. Letter grading. Mr. Wirz (W)

154S. Flight Mechanics, Stability, and Control of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 150A, 150B. Aircraft performance, flight mechanics, stability, and control, some basic ingredients needed for design of aircraft. Effects of airplane flexibility on stability derivatives. Letter grading. Mr. Wirz (F)

155. Intermediate Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102. Axioms of Newtonian mechanics, generalized coordinates, Lagrangian equa-
tion, variational principles; central force motion; kine-
matic and dynamics of rigid bodies, Euler equations, motion of rotating bodies, oscillatory motion, normal coordi-
nates, orthogonality relations. Letter grading. Mr. Gibson (F)

156A. Advanced Strength of Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 82, 101. Not open to students with credit for course 166A. Concepts of stress, strain, and material behavior. Stresses in loaded beams with symmetric and asymmetric cross-
sections. Torsion of cylinders and thin-walled structures, shear flow. Stresses in pressure vessels, press-
fit and shrink-fit problems, rotating shafts. Curved beams. Contact stresses, Strength and failure, plastic deformation, fatigue, elastic instability. Letter grading. Mr. Mal (F,W,Sp)

156B. Mechanical Design for Power Transmis-
sion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Choice of ma-
terial selection in mechanical design. Load and stress analy-

Design project involving computer-aided design (CAD) and finite element analysis (FEA) modeling. Concurrently sched-
uled with course C296A. Letter grading. Mr. Ghoniem (Sp)

157. Basic Mechanical and Aerospace En-
158. Analysis of Aerospace Structures. (4) Lecture, four hours; discussion, two hours. Requisites: courses 101, 102, 103, 105. Electromagnetic Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, rec-
orders, data-acquisition systems. Introduction and ana-
sysis, Letter grading. Mr. Ghoniem, Mr. Ju (F,W,Sp)

157A. Aerospace Design Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Requisites: courses 150A, 157. Recom-
manded: course 150B. Spacecraft design, including two-body and three-body problem, Kepler laws, and Keplerian orbits. Ground track and taxonomy of common or-
bits. Orbital and transfer maneuvers, patched conics, perturbation theory, low-thrust trajectories, space-
craft pointing, and spacecraft attitude control. Space mission design, space environment, rendezvous, re-
eye, and launch. Letter grading. Mr. Kavehpour (Fall)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 102. Recom-
mended: course 150B. Spacecraft design, including two-body and three-body problem, Kepler laws, and Keplerian orbits. Ground track and taxonomy of common or-
bits. Orbital and transfer maneuvers, patched conics, perturbation theory, low-thrust trajectories, space-
craft pointing, and spacecraft attitude control. Space mission design, space environment, rendezvous, re-
eye, and launch. Letter grading. Mr. Wirz (F)

161B. Introduction to Space Technology. (4) Lecture, four hours; outside study, eight hours; outside study, six hours. Recommended preparation: courses 102, 161A. Spacecraft systems and dynamics, including spacecraft power, instruments, communications, propulsion, orbital determination and control. Space mission de-
sign, launch vehicles,considerations, space propul-
sion. Letter grading. Mr. Wirz (W)

161C. Spacecraft Design. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 161B. Preliminary design and analysis by students of Earth-orbiting or interplanetary space missions and spacecraft. Students work in groups of three or four, with each student responsible primarily for one sub-
system and for integration with whole. Letter grading. Mr. Wirz (Sp)

161D. Space Technology Hardware Design. (4) Lecture, four hours; laboratory, four hours; outside study, four hours. Enforced requisite: course 161B. Design by students of hardware with applications to space technology. Designs are then built by HSSEAS professional machine shop and tested by students. Letter grading. Mr. Wirz (Not offered 2018-19)

162A. Introduction to Mechanisms and Mechan-
ical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requi-

162D. Mechanical Engineering Design I. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisites: courses 94, 156A, or M183B, or 163A, or 163B, or 171A, or 171A. Limited to seniors. First of two mechanical engineering capstone design courses. Lectures on engineering project manage-
ment, design of thermal systems, mecha-
nical systems, and mechanical components. Stu-
dents work in teams to begin their two-term design project. Laboratory modules include CAD design, CAD analysis methods, and conceptual design for team project. Letter grading. Mr. Ghoniem, Mr. Tsao (W)

162E. Mechanical Engineering Design II. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 162D. Limited to seniors. Second of two mechanical engineering cap-
stone design courses. Student groups continue de-
sign projects started in course 162D, making use of CAD design lab, laboratory analysis laboratory, and mechatronics laboratory. Design theory, design tools, economics, marketing, manufacturability, quality, in-
tellectual property, design for manufacture and as-
ssembly, design for safety and reliability, and engi-
neering ethics. Students conduct hands-on design, fabrication, and testing of prototype and demon-
strations or competition. Preparation of design project presentations in both oral and written for-
mats. Letter grading. Mr. Ghoniem, Mr. Tsao (Sp)

166A. Analysis of Aerospace Structures. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 82, 101. Not open to students with credit for course 156A. Introduction to two-dimensional elasticity, stress-strain laws, yield and failure, bending design of beams; warping; torsion of thin-walled cross sections: shear flow, shear-lag; combined bending torsion of thin-
walled, stiffened structures used in aerospace vehi-

166B. 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 sym-
matic laminates, failure analysis, design examples and design studies, buckling of composite compo-
nents, stress tensors, micro-mechanics of composites. Letter grading. Mr. Carman (W)

166C. Design of Composite Materials. (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 sym-
matic laminates, failure analysis, design examples and design studies, buckling of composite compo-
nents, stress tensors, micro-mechanics of composites. Letter grading. Mr. Carman (W)

M168. Introduction to Finite Element Methods. (4) Major in Civil Engineering M135C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 156A. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, shape functions, and Ritz approximation methods; shape functions; conversion properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration; Practical use of FEM software; geometric and analytical modeling; preprocessing and postpro-
ccessing techniques; term projects with computers. Letter grading. Mr. Mal (F)

169A. Introduction to Mechanical Vibrations. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 101, 102, 107. Fundamentals of vibration theory and applications. Force, free, and transient vibration of one and two degrees of freedom systems, including damping. Normal modes, coupling, and normal coordinates. Vibration isolation devices, vibrations of continuous systems. Letter grading. Mr. Mal (F)

171A. Introduction to Feedback and Control Sys-
tems. Dynamic Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 107. Introduction to feedback principles, control systems design, and system stability. Modern control systems in en-
171B. Digital Control of Physical Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 171A or Electrical Engineering 141. Analysis and design of digital control systems. Sampling theory. Z-transformation. Discrete-time system representation. Design using classical methods: performance specifications, root loci, frequency response, loop-shaping compensa-
tion. Design using state-space methods: state feed-
back, state estimator, state estimator feedback control.
Simulation of sampled data systems and prac-
tical aspects: roundoff errors, sampling rate selection, computational stability. Letter grading. Mr. M’Closkey (F,Sp)

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 electronic systems. Power spectrum models of noise and disturbances, and performance trade-offs imposed by conflicting re-
quirements. Constraints on sensitivity function and complementary sensitivity function imposed by non-

minimize phase plants. Lecture topics supported by weekly hands-on laboratory work. Letter grading. Mr. M'Closkey (W)

174. Probability and Its Applications to Risk, Reliability, and Quality Control. (4) Lecture; four hours; discussion; two hours; outside study; six hours. Requisite: Mathematics 110A. Introduction to probability theory; random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength analysis, statistical quality control by variables and by attributes, acceptance sampling. Letter grading. Mr. Mosleh (F)

C175A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture; four hours; outside study; eight hours. Enforced requisites: courses 82, 107. Probability spaces, random variables, stochastic sequences and processes, expectation, conditional expectation, Gaussian/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course C271A. Letter grading. Mr. Speyer (F)


182B. Mathematics of Engineering. (4) Lecture; four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses M20 (or Civil Engineering M20) or Computer Science 31). 82. Basic topics from numerical analysis having wide application in solution of practical engineering problems, computer arithmetic, and errors. Solution of linear and nonlinear systems. Algebraic eigenvalue problem. Least-square methods, numerical quadratic forms and quadratic approximations. Numerical solution of initial and boundary value problems for ordinary and partial differential equations. Letter grading. Mr. Zhong (F)


M183B. Introduction to Microscale and Nanoscale Manufacturing. (4) Same as Bioengineering M153, Chemical Engineering M153, and Electrical and Computer Engineering M153.) Lecture; three hours; laboratory; four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 4A, 4AL. Introduction to general manufacturing methods, mechanisms, constraints, and microfabrication and nanofabrication techniques. Includes basic principles of tribology, thermal, and dynamic control systems. Letter grading. Mr. Chiou (FSp)

C183C. Rapid Prototyping and Manufacturing. (4) Lecture; four hours; outside study; six hours. Enforced requisites: course 183A Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technique and product creation in last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables building of parts that have traditionally been impossible to fabricate because of their complex shapes or of variety in materials. In analogy to speed and flexibility of desktop publishing, rapid prototyping is also called desktop manufacturing, with actual three-dimensional objects from two-dimensional images. Methodology of rapid prototyping has also been extended into meso-/micro-/nano-scale to produce three-dimensional functional miniature components. Concurrently scheduled with course C297A. Letter grading.

Mr. Li (W)

184. Introduction to Geometry Modeling. (4) Lecture; four hours; laboratory; four hours; outside study; six hours. Enforced requisites: 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 Beziers 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. Gach (Not offered 2018-19)

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 requisites: course M20 or Civil Engineering M20 or Computer Science 31. Manufacturing today requires assembling of individual components into assembled products, shipping of such products, and eventually use, maintenance, and disposal of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and assemblies of products allow them to be tracked automatically 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 accessed 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. Gach (Sp)


Mr. M'Closkey (F)

C187L. Nanoscale Fabrication, Characterization, and Biointerface Detection. (4) Lecture; two hours; laboratory; three hours; outside study; seven hours. Multidisciplinary course that introduces laboratory techniques of nanoscale fabrication, characterization, and biointerface detection. Basic physical, chemical, and biological principles related to these techniques, top-down and bottom-up (self-assembly) nanomaterials, nanodevice characterization (AFM, SEM, etc.) and optical and electrochemical biosensors. Students encouraged to create their own ideas in original experimental research. Concurrently scheduled with course C287L. Letter grading. Mr. Y. Chen (Sp)

188. Special Courses in Mechanical and Aerospace Engineering. (2 to 4) Lecture, two to four 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 those taught by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. P/NP or letter grading. (Not offered 2018-19)

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. Student presentation of projects in research specialty. May be repeated for credit. P/NP or letter grading.

199. Directed Research in Mechanical and Aerospace Engineering. (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Culminating paper or project required. May be repeated for credit. P/NP or letter grading. F(W)Sp

Graduate Courses


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 transfer in absorbing, emitting, and scattering media. Applications cover laser-material interactions in addition to traditional areas such as combustion and thermal insulation. Letter grading. Mr. Pilon (W)


231G. Microscopic Energy Transport. (4) Lecture; four hours; outside study, eight hours. Requisite: course 105D. Heat carriers (photons, electrons, phonons, molecules) and their energy characteristics, statistical properties of heat carriers, scattering and propagation of heat carriers, Boltzmann transport equations, derivation of classical laws from Boltzmann transport equations, deviation from classical laws at small scale. Letter grading. Mr. Ju (F)

233. Nanoscience for Energy Technologies. (4) Lecture; four hours; outside study, eight hours. Introduction to fundamental principles of energy transport, conversion, and storage at nanoscale, and recent development for these energy technologies involving nanostructures. Focus on basics of thermal science, solid-state quantum mechanics, electro-magnetics, and statistical physics. Topic discussions given for examples that connect technological application, fundamental challenge, and scientific-solution-based nanotechnology to fundamental performance and energy efficiency. Letter grading. Mr. Hu (Sp)
235A. Nuclear Reactor Theory. (4) Lecture, four hours; discussion, two hours. Underlying physics and mathematics of nuclear reactor (fission) core design. Diffusion theory, reactor kinetics, slowing down and thermalization, multigroup methods, introduction to transients. Letter grading. Mr. J. Kim (W)

C237. 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; solar and wind generation intermittency and correction; microgrids; grid stability; energy storage and electric vehicles; simulation; monitoring; distribution network; grid code; consumer-centric technologies; sensors, communications, and computing; wireless, wireline, 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. J. Kim (F)

M237B. Fusion Plasma Physics and Applications. (Same as Electrical and Computer Engineering M287.) Lecture, four hours; outside study, eight hours. Fundamentals of plasmas at thermonuclear burning conditions; the Chandrasekhar-Planck equation; applications to heating by neutral beams, RF, and fusion reaction products. Bremsstrahlung, synchrotron, and atomic radiation processes. Plasma surface interactions. Fluid description of burning plasma. Dynamics, stability, and control. Oceanic applications in current and tandem mirrors, and alternate concepts. Letter grading. Mr. Abdou (Not offered 2018-19)


239B. Seminar: Current Topics in Transport Phenomena. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, tutorials, presentations, and projects in areas of current interest in transport phenomena. May be repeated for credit. S/U grading.

239F. Special Topics in Transport Phenomena. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced and current study of one or more aspects of heat and mass transfer, such as turbulence, stability and transition, buoyancy effects, variational methods, and measurement techniques. May be repeated for credit with topic change. S/U grading.

239G. Special Topics in Nuclear Engineering. (2 to 4) Lecture, two to four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, risk-benefit trade-offs, nuclear materials, and radiation effects. 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. Design 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, advanced transport models and concepts, inertial fusion, fission-fusion hybrid systems, and fusion reactor safety. May be repeated for credit with topic change. S/U grading.

CM240. Introduction to Biomechanics. (4) (Same as Bioengineering CM240.) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: courses 101, 102, and 156A or 168A. Introduction to fundamental biological and mechanical concepts and models to explain several devices manufactured with multifunctional materials, with focus on the development of composite materials. Letter grading. Mr. Gupta (W)


242. Introduction to Multiferroic Materials. (4) Lecture, four hours; outside study, eight hours. Overview of different types of multiferroic materials, including strontium barium titanate and ferroelectrics; single and multiferroics, as well as fundamental physics underlying ferroelectricity and ferromagnetism. Material science description of these materials, with focus on line and nonlinear behavior with associated mechanisms such as spin reorientation. Presentation of analytical tools necessary to predict material response ranging from constitutive relations to gov- erning equations, including elastodynamics and Maxwell's equations. Analytical and physical descriptions used to explain several devices manufactured with multifunctional materials, including magnetometers, memory devices, motors, and antennas. Letter grading. Mr. Carman (Sp)

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requires: course 150A. Corequisite: course 182B. Development and application of fundamental principles of fluid mechanics at graduate level, with emphasis on compressible flow. Flow kinematics, basic equations, constitutive relations, exact solutions on the Navier/Stokes equations, vorticity dynamics, decomposition of flow fields, potential flows. Letter grading. Mr. Eldredge, Mr. J. Kim (W)

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requires: course 150A. Fundamental principles of fluid dynamics and thermal-convective processes, including the Navier-Stokes equations discussed in advanced 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. Requires: courses 150A, 150B. Effects of compressibility in viscous and incompressible flows. Steady and unsteady inviscid subsonic and supersonic flows; method of characteristics; small disturbance theories (linearized and hyperbolic); shock dynamics. Letter grading. Ms. Karagozian, Mr. Zhong (F)


250M. Introduction to Microfluids/Nanofluids. (4) Lecture, four hours; outside study, eight hours. Requires: course 150A. Introduction to fundamentals of micro/nano fluidics, mechanisms. Letter grading. Mr. Kavehpour (Not offered 2018-19)

C250P. Aircraft Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requires: courses 105A, 150A. Thermodynamic properties of gases, aircraft jet engine cycle analysis and component performance, component matching, advanced aircraft engine topics. Concurrently scheduled with course C150P. Letter grading. Ms. Karagozian (Not offered 2018-19)

C252R. Rocket Propulsion Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 105A. Rocket propulsion concepts, including chemical rockets (liquid, gas, and solid propellants), hybrid rocket engines, electric (ion, plasma) rockets, nuclear rocket engines. Overview of current and future issues in launch vehicle technologies. Concurrently scheduled with course C150R. Letter grading. Ms. Karagozian, Mr. Wirz (Not offered 2018-19)

252A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requires: course 150A. Mechanisms by which laminar flows can become unstable and lead to turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; blob-flux, layer instability. Nonlinear aspects: sufficient criteria for stability, subcritical instabilities, supercritical states, transition to turbulence. Letter grading. Mr. Zhong (W)

252B. Turbulence. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Requires: courses 150A, 150B. Characteristics of turbulent flows, conservation and transport equations, statistical description of turbulent flows, scales of turbulent motion, simple turbulent flows, free-shear flows, wake and boundary layers, turbulence modeling, numerical simulations of turbulent flows, and turbulence control. Letter grading. Ms. Karagozian, Mr. J. Kim (Not offered 2018-19)

252C. Fluid Mechanics of Combustion Systems. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Requires: courses 150A, 150B. Review of fluid mechanics and chemical thermodynamics applied to reactive systems,

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: molecular collisions, distribution functions and averaging, semiempirical and ab initio potential surfaces, trajectory calculations, statistical reaction rate theories. Practical examples of large-scale chain mechanisms from combustion chemistry of several elements, Letter grading. Ms. Karagopian (Not offered 2018-19)

252P. Plasma and Ionized Gases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses B2, 102, 150A, 152B. Neutral and charged particle motion, magnetohydrodynamics, two-fluid plasma treatments, ion and electron diffusion, gas diffusion, Child/Langmuir law, basic plasma devices, electron emission and work function, thermal distributions, vacuum and vacuum systems, space-charge, particle collisions and ionization, plasma discharges, sheaths, and electrostatics. Letter grading. Mr. Wierz (Not offered 2018-19)

254A. Special Topics in Aerodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 82, 150A, 150B, 182B, 182C. Special topics of current interest in advanced aerodynamics. Emphasis on integral, potential flow, sonic booms, and unsteady aerodynamics. Letter grading. Mr. Zhong (Not offered 2018-19)

255A. Advanced Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 155, 169A. Vibration and Lagrange equations. Kinetodynamics and kinetics of rigid bodies; procession and nutation of spinning bodies. Letter grading. Mr. Gibson (Sp)

255B. Mathematical Methods in Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255A. Concepts of stability; state-space interpretation; stability determination by simulation, linearization, and Lyapunov direct method; the Hamiltonian as a Lyapunov function; Lagrange equations. Kinematics and dynamics of rigid bodies; procession and nutation of spinning bodies. Letter grading. Mr. Gibson (Sp)

256A. Linear Elasticity. (4) (Same as Civil Engineering M230A) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 156B. Linear elastostatics. Cartesian tensors; infinitesimal strain tensor; Cauchy stress; strain energy; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions; cracks; three-dimensional problems of Kelvin, Boussinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading. Mr. W. Ju, Mr. Mal (W)

256B. Nonlinear Elasticity. (4) (Same as Civil Engineering M230B) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stress; field equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoelasticity, linearization of field equations; solution of selected problems. Letter grading. Mr. W. Ju, Mr. Mal (W)

256C. Plasticity. (4) (Same as Civil Engineering M230C) Lecture, four hours; outside study, eight hours. Requisite: courses M256A, M256B. Classical rate-independent plasticity theory, yield functions, flow rules, yield surfaces, yield surface rate-dependent viscoplasticity, Perzyna and Duvernay/Lions types of viscoplasticity. Thermoplasticity and creep. Return mapping algorithms for plasticity and viscoplasticity. Finite element implementations. Letter grading. Mr. W. Ju, Mr. Mal (W)

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 for calculation of crack tip stress intensity factors; calculation of energy release rates in stiffened structures, pressure vessels, plates, and shells. Letter grading. Mr. Gupta (Sp)

M257A. Elastodynamics. (4) (Same as Earth, Planetary, and Space Sciences M224A) Lecture, four hours; outside study, eight hours. Requisites: courses M256A, M256B. Equations of linear elasticity, Cauchy equation of motion, constitutive relations, boundary and initial conditions, principle of energy. Sources and waves under internal sources, dissipation, and finite amplitude waves. Solid-state problems. Guided waves in layered media. Applications to dynamic fracture, nondestructive evaluation (NDE), and mechanics of earthquakes. Letter grading. Mr. Mal (Not offered 2018-19)

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 to the nanoscale and up to continuum. Discussion of atomistic simulation methods (e.g., molecular dynamics, molecular statics), nanoscale 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 roughness, quantum dots, nanotubes, nanoclusters, thin films (e.g., optical thermal barrier coatings and ultrastrong nanolayer materials), nanoindentation, smart (active) materials, nano- and micro- and micromachining, and torsion. Letter grading. Mr. Ghoniem (Not offered 2018-19)

259A. Seminar: Advanced Topics in Fluid Mechanics. (4) Seminar, four hours; outside study, eight hours. Requisites: courses 259A, 259B. 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, Mr. Spearrin (Not offered 2018-19)

259B. Seminar: Advanced Topics in Solid Mechanics. (4) Seminar, four hours; outside study, eight hours. Advanced study in various fields of solid mechanics, topics selected from term to term. Topics include dynamics, elasticity, plasticity, stability, and fracture of solids. Letter grading. Mr. Mal (W)

260. Current Topics in Mechanical Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Enforced requisites: courses 260A, 260B. Seminar for mechanical- and aerospace engineering students. Lectures, discussions, and student presentations and projects in areas of current interest in mechanical engineering. May be repeated for credit. S/U grading.

261A. Energy and Computational Methods in Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Review of theory of linear elasticity and reduced-dimension structural dynamics, and nonautonomous systems; averaging and perturbation methods of nonlinear analysis; parametric excitation and non- linear resonance. Application to mechanical systems. Letter grading. Mr. Mal (W)

261B. Finite Element Analysis for Solids and Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: courses M256A or M256A- Consent of instructor. Strongly recommended requisites: courses M168, M256B, 261A. Application of finite element method to classical and state-of-art modeling and design for solids and structures. Introduction of commercial mainstream finite element program—ABAQUS—and demonstration of how to use it in advanced way. Topics include review of finite element method, linear elasticity, finite deformation of hyperelastic materials; instability analysis, fracture, and implementation of user-defined subroutines in ABAQUS. Term projects using computers. Letter grading. Mr. Mal (Not offered 2018-19)

262. Mechanics of Intelligent Material Systems. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 166C. Constitutive relations for electro-magneto-mechanical materials. Fiber-optic sensor technology, Micro/macrowave analysis, including classical linearization theory, shear lag theory, concentric cylinder analysis, hexagonal models, and homogenization, techniques and applications to active materials. Active systems design, inch-worm, and biomimetic approach. Letter grading. Mr. Carman (Sp)

263A. Kinematics of Robotic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 255B. Dynamics models of serial and parallel robotic manipulators, including compliant linkages, control of manipulators, and transformations along with direct and inverse kinematics, linear and angular velocities, Jacobian matrix (velocity and force), velocity propagation method, force-orientation methods, application of Lagrangian dynamics, manipulator dynamics (Newton/ Euler formulation, Lagrangian formulation), trajectory generation, introduction to parallel manipulators. Letter grading. Ms. Santos (Sp)

263B. Dynamics of Robotic Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 255B. Sensors, actuators, and control schemes for robotic systems, including computed torque control, linear feedback control, and force feedback control, and advanced control topics from nonlinear and adaptive control, hybrid control, nonholonomic systems, vision-based control, and perception. Letter grading. Mr. Hong (W)

263C. Control of Robotic Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 253B. Sensors, actuators, and control schemes for robotic systems, including computed torque control, linear feedback control, and force feedback control, and advanced control topics from nonlinear and adaptive control, hybrid control, nonholonomic systems, vision-based control, and perception. Letter grading. Mr. Hong (W)


269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269B. Current and advanced topics in robotics and control, including kine- matics, dynamics, control, and implementation of advanced sensors and actuators, flexible links, manipula- bility, redundant manipulators, human-robot interaction, teleoperation, haptics. Letter grading. Mr. Mal (W)

270A. Linear Dynamic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 270A. Presentation of field of aeroelasticity for undergraduate and graduate students. Introduction to suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady air loads from governing variational principles. Flow in- duced instability and response of structures. Letter grading. Mr. Mal (Not offered 2018-19)

270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical and Computer Engineering M240A) Lecture, four hours; outside study, eight hours. Requisite: course 171A or
Electrical and Computer Engineering M 240 C. Lecture, four hours; outside study, eight hours. Requisite: course M 270 A or Electrical Engineering M 240 A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time systems, finite-time and infinite-time problems; Hamiltonian systems and optimal control; algebraic and differential Riccati equations; applications of controllability, stabilizability, observability, and detectability solutions. Letter grading.

M 270 C. Optimal Control. (4) (Same as Chemical Engineering M 290 C and Electrical and Computer Engineering M 240 C.) Lecture, four hours; outside study, eight hours. Requisite: course 270 B. Applications of variational methods, Pontryagin maximum principle, Hamiltonian equation (dynamic programming) to optimal control of dynamic systems modeled by nonlinear ordinary differential equations. Letter grading. Mr. Sper (Not offered 2018–19)

C 271 A. Probability and Stochastic Processes in Dynamical Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course C 271 B. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, conditional mean and risk estimators. Letter grading. Mr. Gibson (W)

C 271 C. Stochastic Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course C 271 B. Stochastic dynamic programming, certainty equivalence principle, separation theorem, information state, stochastic-Gaussian and stochastic-linear-exponential-Gaussian problem. Relationship between stochastic control and robust control. Letter grading. Mr. Sper (F)

C 271 D. Seminar: Special Topics in Dynamic Systems Control. (4) Lecture, 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. Sper (Not offered 2018–19)

M 272 A. Nonlinear Dynamics. (4) (Same as Chemical Engineering M 282 A and Electrical and Computer Engineering M 242 A.) Lecture, four hours; outside study, eight hours. Requisite: course M 270 A or Chemical Engineering M 280 A or Electrical and Computer Engineering M 240 A. State-space techniques for studying solutions of time-invariant and time-varying nonlinear dynamic systems with emphasis on stability, Lyapunov theory (including converse theorems), invariance, center manifold theorem, input-to-state stability and small-gain theorem. Letter grading. (Not offered 2018–19)

C 273 A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Requisites: courses C 171 A, M 270 A. Graduate-level introduction to analysis and design of robust 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 model reduction. Letter grading. Mr. M'Closkey (Sp)

275 A. System Identification. (4) Lecture, four hours; outside study, eight hours. Methods for identification of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include transfer functions and state-space models. Discussions of applications in manufacturing, industrial and aerospace engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading.

M 276. Dynamic Programming. (4) (Same as Electrical and Computer Engineering M 237 L.) Lecture, four hours; outside study, eight hours. Recommended requisite: Electrical and Computer Engineering 232 A or 236 A or 236 B. Introduction to mathematical analysis of sequential decision processes. Finite horizon model in both deterministic and stochastic cases. Finite-state infinite horizon model. Methods of solution. Examples from inventory theory, finance, optimal control and estimation, Markov decision processes, combinatorial optimization, communications. Letter grading. (Not offered 2018–19)

C 277 A. Advanced Digital Control for Mechatronic Systems. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: courses 271 B, M 270 A. Digital signal processing and control analysis of mechatronic systems. System inversion-based digital control algorithms and robustness properties. Youla parameterization of stabilizing controllers, previewed optimal feedback compensator, repetitive and learning control, and adaptive control. Real-time control investigation of topics to selected mechatronic systems. Letter grading. Mr. Tsao (Sp)

C 279. Dynamics and Control of Biological Oscillations. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 107, M 270 A. Analysis and design of oscillatory systems. Introduction to mathematical analysis of biological systems. Introduction to the control of oscillatory systems. Topics include neuronal information processing through action potentials (spike train), central pattern generator, coupled nonlinear oscillators, optimal gait (periodic motion) for animal locomotion, and entrainment to natural oscillations via feedback control. Letter grading. Mr. Iwasaki (Not offered 2018–19)

M 280 B. Microelectromechanical Systems (MEMS) Fabrication. (4) (Same as Bioengineering M 252 B and Electrical and Computer Engineering M 252 B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M 183 B. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading. Mr. C-J. Kim (W)

C 281. Microsensors. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102, 103, 105 D. Fundamental issues of being in microscopic world and mechanical engineering of microscale devices. Topics include scale issues, surface tension, superhydrophobic surfaces and applications, and electro wetting and applications. Letter grading. Mr. C-J. Kim (Not offered 2018–19)

C 282. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) (Same as Bioengineering M 252 L and Electrical and Computer Engineering M 252 L.) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to MEMS device physics, device design, scaling rules, 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. Chiou (Not offered 2018–19)

284. Sensors, Actuators, and Signal Processing. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 82, 103, 105 A, 105 D. Introduction to fundamental physical principles and performance requirements of micro transducers. Applications of using unique properties of micro transducers for distributed and real-time control of engineering problems. Letter grading. Mr. C-J. Kim (W)


C 287. Nanoscience and Technology. (4) (Same as Electrical and Computer Engineering M 257 L.) Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembling) characterizations; nanomaterials, nanoelectronics, and nanobiochemistry technology. Introduction to new methodologies in nano areas to understand scientific principles and nano technology and inspire students to create new ideas in multidisciplinary areas. Letter grading. Mr. Y. Chen (W)

C 287 L. 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-assembling) nanofabrication, nanocharacterization (AEM, SEM, etc.), and optical and electrochemical bioensors. Students will develop and present new ideas in self-designed experiments. Concurrently scheduled with course C 186 L. Letter grading. Mr. Y. Chen (Sp)

C 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, thermal physics, mechanical properties, and chemical, carrier, etc.) in laser microfabrication, state-of-art optics and instrument for laser microfabrication, applications such as rapid prototyping, surface modification, and microsystems. Lecture grading. Mr. Y. Chen (Sp)
294A. Compliant Mechanism Design. (4) (Formerly numbered 294B.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or equivalent. Design and analysis of compliant mechanisms, compliant actuators, MEMs, optical mounts, and nanoscale positioning systems. Hands-on exercises include build-your-own flexure kits, CAD and FEA simulations, and term project. Letter grading. Mr. Hopkins (W)

295A. Radio Frequency Identification Systems: Analysis, Design, and Applications. (4) Lecture, four hours; outside study, eight hours. Designed for graduate engineering students. Examination of emerging discipline of radio frequency identification (RFID), including basics of RFID, how RFID systems function, design and analysis of RFID systems, and applications to fields such as supply chain, manufacturing, retail, and homeland security. Letter grading. Mr. Li (Not offered 2018-19)

296B. High-Temperature Mechanical Design. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or equivalent. Review of elasticity and continuum thermodynamics, multiaxial plasticity, flow rules, cyclic plasticity, viscoplasticity, creep, creep damage in cyclic loading. Damage mechanics: thermodynamics, ductile, creep, fatigue, and fatigue-creep interaction damage. Fracture mechanics: elastic and elastoplastic analysis, J-integral, brittle fracture, ductile fracture, fatigue and creep crack propagation and design for high-temperature components as turbine blades, pressure vessels, heat exchangers, connecting rods. Design project involving CAD and FEM modeling. Concurrently scheduled with course C156B. Letter grading. Mr. Ghoniem (Sp)

297A. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Recommended requisite: level of knowledge in manufacturing equivalent to course 183A and CAD capability. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technology to accelerate product creation in last two decades. Machine for layered manufacturing builds parts directly from CAD models. This novel manufacturing technology enables building of parts that have traditionally been impossible to fabricate because of their complex shapes or of variety in materials. In analogy to speed and flexibility of desktop publishing, rapid prototyping is also called desktop manufacturing, with actual three-dimensional solid objects instead of mere two-dimensional images. Methodology of rapid prototyping has also extended into mini-/micro-/nano-scale to produce three-dimensional functional miniature components. Concurrently scheduled with course C183C. Letter grading. Mr. Li (W)

297B. Material Processing in Manufacturing. (4) (Formerly numbered 297A.) (Same as Materials Science M297B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 183A. 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. Li (Not offered 2018-19)

M297C. Composites Manufacturing. (4) (Formerly numbered 297D.) (Same as Materials Science M297C.) Lecture, four hours; outside study, eight hours. Requisites: course 166C, Materials Science 151. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, metal and ceramic matrix composites, quality assurance. Letter grading. Mr. Ghoniem (Not offered 2018-19)

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate mechanical and aerospace engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged. May be repeated with topic change. Letter grading. (Not offered 2018-19)

M299A. Seminar: Systems, Dynamics, and Control Topics. (2) (Same as Chemical Engineering M297 and Electrical and Computer 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 research results. Letter grading. Mr. Mal (F,Sp)

597A. Preparation for MS Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Reading and preparation for MS comprehensive examination. S/U grading. Mr. Li (F,Sp)

597B. Preparation for PhD Preliminary Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Reading and preparation for PhD comprehensive examination. S/U grading. Mr. Li (F,Sp)

598. Research for and Preparation of MS Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Supervised independent research for MS candidates, including thesis prospectus. S/U grading. Mr. Li (F,Sp)

599. Research for and Preparation of PhD Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate mechanical and aerospace engineering students. Supervised independent research for PhD candidates, including dissertation writing. S/U grading. Mr. Li (F,Sp)

**Master of Science in Engineering Online Programs**

For information on graduate admission, see Graduate Programs on page 25.

The following introductory information is based on 2018-19 program requirements for UCLA graduate degrees. Complete program requirements are available at https://grad.ucla.edu/academics/graduate-study/program-requirements-for-ucla-graduate-degrees/. Students are subject to the detailed degree requirements as published in program requirements for the year in which they enter the program.

The primary purpose of the Master of Science in Engineering online degree programs 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 programs offer 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. programs are 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.

**Scope and Objectives**

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**Graduate Study**

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M.S. in Engineering Online Programs

Course Requirements
The programs consist 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 programs are 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 programs can be completed within two academic years plus one additional term.

Areas of Study

Data Science Engineering Program
Junghoo (John) Cho, Ph.D. (Computer Science), Area Director; cho@cs.ucla.edu
Vwani P. Roychowdhury, Ph.D. (Electrical and Computer Engineering), Area Director; vwani@ee.ucla.edu

The exponential growth of data generated by machines and humans present unprecedented challenges and opportunities. From the analysis of this big data, businesses can learn key insights about their customers to make informed business decisions. Scientists can discover previously unknown patterns hidden deep inside the mountains of data. In this program, students will learn key techniques used to design and build big data systems and gain familiarity with data-mining and machine-learning techniques that are the foundations behind successful information search, predictive analysis, smart personalization, and many other technology-based solutions to important problems in business and science.

Engineering Management Program
Leslie M. Lackman, Ph.D. (Mechanical and Aerospace Engineering), Area Director; llackman@support.ucla.edu

The engineering management program focuses on providing entering and current engineering management personnel an opportunity to expand their business-related knowledge base and skills to enhance employment performance to the benefit of both the employee and employer. The program offers similar curriculum to that currently offered on campus by the professional schools.

All Internet-available lecturers are offered 24/7, with a weekly homeroom time to enhance the taped lectures and promote class interaction. The homerooms are held in early evenings to facilitate nonimpact with employee work schedules.

Environment and Water Resources Program
Jennifer A. Jay, Ph.D. (Civil and Environmental Engineering), Area Director; jjay@seas.ucla.edu

Plentiful high-quality water is fundamental for society. However, drought, climate change, contamination, and growing populations pose challenges for water sustainability. Engineers are needed worldwide to find novel solutions in providing access to clean water. Key elements in this degree program are surface and groundwater processes, hydroclimatology, watershed response to disturbance, remote sensing for hydrologic applications, membrane separation in aqueous systems, aquatic chemistry, environmental microbiology, and the chemical fate, geochemical modeling, and transport of contaminants in the environment.

Mechanics of Structures Program
Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Area Director; ajit@seas.ucla.edu

The main objective of the mechanics of structures program is to provide students with the opportunity to develop 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, 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 popular finite element packages for solving realistic structural analysis problems.

Systems Engineering Program
Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Interim Area Director; jyang@seas.ucla.edu

Systems 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.

M.S. in Engineering—Aerospace
Xiaolin Zhong, Ph.D. (Mechanical and Aerospace Engineering), Area Director; xiaolin@seas.ucla.edu

The objective of this program is to provide students with a broad knowledge of major technical areas of aerospace engineering in order to fulfill the current and future needs of the aerospace industry. The major technical areas of this program include aerodynamics and computational fluid dynamics (CFD), propulsion, systems and control, and structures and dynamics. Undergraduate and graduate courses in the area of aerospace engineering cover a wide range of fundamental concepts of the science and engineering of aerodynamics, space technology, compressible flow, computational aerodynamics, aircraft and rocket propulsion systems, digital control of physical systems, linear dynamic systems, linear optimal control, design of aerospace structures, dynamics of structures, robust control system analysis and design, and probability and stochastic processes in dynamical systems.

M.S. in Engineering—Computer Networking
Mario Gerla, Ph.D. (Computer Science), Area Director; gerla@cs.ucla.edu

Three undergraduate elective courses complement the basic background of the undergraduate 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.

M.S. in Engineering—Electrical
Izhak Rubin, Ph.D. (Electrical and Computer Engineering), Area Director; rubin@ee.ucla.edu

The electrical engineering program covers a broad spectrum of specializations in communications and telecommunications, control systems, electromagnetics, embedded computing systems, engineering optimiza-
tion, integrated circuits and systems, micro-electromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

**M.S. in Engineering—Electronic Materials**

Ya-Hong Xie, Ph.D. (Materials Science and Engineering), Area 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.

**M.S. in Engineering—Integrated Circuits**

Dejan Markovic, Ph.D. (Electrical and Computer Engineering), Area Director; dejan@ee.ucla.edu

The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signaling and synchronization, VLSI signal processing, and communication system design. Summer courses are not yet offered in this program; therefore it cannot currently be completed in two calendar years.

**M.S. in Engineering—Manufacturing and Design**

Nasr M. Ghoniem, Ph.D. (Mechanical and Aerospace Engineering), Area Director; ghoniem@ucla.edu

An advanced program of study that covers fundamental and applied topics in modern manufacturing and mechanical design. The program includes finite element methods in design, mechanics of intelligent material systems, nano- and micro-manufacturing, material processing, rapid prototyping, composites manufacturing, design with composites, digital control, design of power transmission systems, design of high-temperature components, and design of smart grids. The program prepares students with the higher educational background and the competence that are necessary for today's rapidly changing technology needs.

**M.S. in Engineering—Materials Science**

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Area 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.

**M.S. in Engineering—Mechanical**

Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Area Director; ajit@seas.ucla.edu

An advanced program of study that covers fundamental and applied topics in modern manufacturing and mechanical design. The program includes finite element methods in design, mechanics of intelligent material systems, nano- and micro-manufacturing, material processing, rapid prototyping, composites manufacturing, design with composites, digital control, design of power transmission systems, design of high-temperature components, and design of smart grids. The program prepares students with the higher educational background and the competence that are necessary for today's rapidly changing technology needs.

**M.S. in Engineering—Signal Processing and Communications**

Izhak Rubin, Ph.D. (Electrical and Computer Engineering), Area Director; rubin@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.

**M.S. in Engineering—Structural Materials**

Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Area Director; jyang@seas.ucla.edu

The program provides students with a broad knowledge of 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.
Schoolwide Programs, Courses, and Faculty

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 25.

Lower-Division Courses

10A. Introduction to Complex Systems Science. (5) Lecture; four hours; outside study, eight hours. How many complex systems emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control. Such emergent order, whose ex- planation 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 goes beyond traditional mathematics and statistics in its use of multilayer computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

Mr. Bragan (Not offered 2018-19)

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

20. First-Year Engineering Transition Bridge. (2) Seminar; three hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Recommended to incoming computing students in foundation concepts and principles of computer science, with focus on fundamental computer programming principles, methodologies, and techniques. Basic concepts of programming and C++ computing language. Offered in summer only. P/NP grading.

22. Summer Bridge Program for Enhancing En- gineering Students. (Seminar, 32 hours. Designed primarily for new students to help them understand UCLA, its culture, structure, and academic policies and to facilitate their transition from high school to college. Examination of research on first-year experience of college students, studying at UCLA versus high school, policies and procedures, and campus resources. Intensive introduction of advanced topics covered in upper-division engineering courses. Offered in summer only. P/NP grading.

87. Introduction to Engineering Disciplines. (4) Lecture; four hours; outside study, four hours. Introduction to engineering as professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team process. Investigation of national need underlying current effort to increase participation of historically underserved groups in U.S. techno- logical work force. Letter grading. Mr. Wesel (F)

95. Internship Studies in Engineering. (2 to 4) Tutorial; two to four hours. Limited to freshmen/sopho- mores. Internship studies course supervised by asso- ciate dean or designated faculty member. Further supervision to be provided by organization for which students are doing internship. Students may be required to meet on regular basis with instructor and provide periodic reports of their experience. May not be applied toward major requirements. Be re- peated for credit. Individual contract with associate dean required. P/NP grading. Mr. Wesel (F;W;Sp)

96A. Introduction to Engineering Design. (2) Formerly numbered 96B. Lecture; one hour; laboratory; one hour; outside study, four hours. Recommended for undergraduate Aerospace, Bioengineering, Computer Science, Electrical Engineering, and Mec- hanical Engineering majors. Introduction to engi- neering design while building teamwork and communica- tion skills and examination of engineering majors offered at UCLA and of engineering careers. Completion of hands-on engineering design projects, preparation of short report describing projects, and presentation of results. Specific project details and relevant majors explored with instructor. Letter grading.

Mr. Reiher (G)

96B. Introduction to Engineering Design: Digital Imaging. (2) Lecture; one hour; laboratory; one hour; outside study, four hours. Recommended for undergraduate Aerospace, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communica- tion skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art solid-state imaging devices. How to focus, expose, record, and manipu- luate telescopc images. Development of photographic technology from early chemical experiments to wide spread use of cell phone camera. Completion of hands-on engineering design projects, preparation of short report describing projects, and presentation of results. Letter grading. Mr. Stafsudd (F;Sp)

96C. Introduction to Engineering Design: Internet of Things. (2) Lecture; one hour; laboratory; one hour; outside study, four hours. Recommended for undergraduate Aerospace, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communica- tion skills and examination of engineering majors offered at UCLA and of engineering careers. Hands-on experience with state-of-art Internet of things (IoT) technology to offer students opportunity to rapidly develop inspiring systems that provide ideal introduction to computing systems and IoT applications specific to their major field. IoT technology has become one of most important ad- vances in technology history with applications ranging from wearable health monitoring, to residential monitoring systems, natural resource protec- tion and management, intelligent vehicles and trans- portation systems, robotics systems, and energy conservation. Completion of hands-on engineering design projects, preparation of short report de- scribing projects, and presentation of results. Letter grading. Mr. Kaiser (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. Participation in faculty supervised research project. Students must be in good academic standing and enrolled in minimum of 12 units (ex- cluding this course). Individual contract required; course must be taken for credit. May be re- peated. P/NP grading.

Upper-Division Courses

M101. Principles of Nanoscience and Nanotechnol- ogy. (4) (Same as Materials Science M101.) Lecture, four hours; outside study, eight hours. Requisites: chemistry 1A; physics 1A. Introduction to current progress in engineering to inte- grate biosciences and nanosciences into synthetic systems, where biological components are reengi- neered and rewired to perform desirable functions in both intracellular and cell-free environments. Discuss- ion of basic technologies and systems analysis that deal with dynamic behavior, noise, and uncertainties. Design project in which students are challenged to design novel biosystems and nanosystems for non- trivial task required. Letter grading.

Mr. Liao (F)

M103. Environmental Nanotechnology: Implica- tions and Applications. (4) (Same as Civil Engi- neering M106.) Lecture, four hours; discussion, two hours; outside study, seven hours. Requisite: chemistry 1A. Recommended re- quisite: course M101. Introduction to potential implica- tions of nanotechnology to environmental systems as well as potential application of nanotechnology to en- vironmental protection. Techniques include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) trans- port, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nano- technology for energy and water production, plus en- vironmental protection, monitoring, and remediation. Letter grading. Mr. Hoek (Sp)

110. Introduction to Technology Management and Economics for Engineers. (4) Lecture; four hours; discussion, one hour; outside study, seven hours. Fundamental principles of micro-level (individual, firm, and industry) and macro-level (government, international economics) economics. Core topics include technology management. How individuals, firms, and govern- ments impact successful commercialization of high technology products and services. Letter grading.

Mr. Monbouquet (F;W)

111. Introduction to Finance and Marketing for Engineers. (4) Lecture; four hours; discussion, one hour; outside study, seven hours. Critical compo- nents of finance and marketing research and practice as they impact management of high-technology commer- cialization. Internal (within firm) and external (in market)place marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, return on assets, return on equity, return on invest- ment, interest rates, cost of capital, and product, price, positioning, and promotion. Use of market re- search, segmentation, and forecasting in manage- ment of technological innovation. Letter grading.

Mr. Monbouquette (W;Sp)
112. Laboratory to Market, Entrepreneurship for Engineers. 4 hours; discussion, four hours; outside study, seven hours. Critical components of entrepreneurship, finance, marketing, human resources, and accounting disciplines as they impact entrepreneurship. Emphasis on research and writing within engineering environments. Writing and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading. Limited to seniors. Mr. Wesel (W).

113. Product Strategy. 4 hours; discussion, one hour; outside study, seven hours. Designed for juniors/seniors. Introduction to current management concept of product development. Technical issues and writing form. Satisfies engineering writing requirement. Letter grading. Mr. Wesel (W).

182EW. Technology and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Requisite: English Composition 3, and one course from Civil Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170, Mechanical and Aerospace Engineering 174, or Statistics 100A. Not open for credit to students with credit for course 192EW. Discussion of engineering in broader societal context through examination of some of key ethical, legal, and regulatory issues and frameworks relevant to engineering practice. Explores how society values in relation to these issues. Emphasis on research and writing within engineering environments. Writing and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading. Mr. Wesel (W).

183EW. Engineering and Society. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or 2H or English as a Second Language 36. Not open for credit to students with credit for course 192EW. Designed for sophomore/junior/senior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and on development of moral and ethical values. Contemporary environmental, biological, and legal, and other issues created by new technologies. Emphasis on research and writing within engineering environments. Writing and revision of about 20 pages total, including two individual technical essays and one team-written research report. Reading addresses technical issues and writing form. Satisfies engineering writing requirement. Letter grading. Mr. Wesel (W).

185EW. Art of Engineering Endeavors. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or 2H or English as a Second Language 36. Not open for credit to students with credit for course 183EW. Designed for senior/junior engineering students. Non-technical skills and experiences necessary for engineering career success. Important aspects of group dynamics in engineering practice. Teamwork and effective group skills in engineering environments. Organization and control of multidisciplinary complex engineering projects. Forms of leadership and qualities and characteristics of effective leaders. How engineers, computer sciences, and technology relate to major ethical and social issues. Societal demands on practice of engineering. Emphasis on research and writing in engineering environments. Satisfies engineering writing requirement. Letter grading. Mr. Wesel (F,W,Sp).

186 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 instructor change. Letter grading.

191. Seminar Series in Engineering Research. (1) Seminar, one hour. Seminar series in cutting-edge engineering research at UCLA. Each seminar is given by UCLA graduate students with BS degrees in STEM (science, technology, engineering, and mathematics) major. Majors. Open to undergraduate students interested in graduate research experience. Also offers course petition for graduate students interested in learning about what their peers are doing. P/NP grading.

192. Fundamentals of Engineering Mentorship. (2) Seminar, two hours; outside study, four hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology programs. Review of fundamentals of program planning, organizational structure, implementation, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading. Mr. Wesel (F,W,Sp).

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 major requirements. May be repeated for credit. Individual contract with associate dean required. P/NP grading. Mr. Pottie (F,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 major elements of system engineering process. Coverage of key elements: system requirements, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management, review and audit activities and documentation. 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, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management, review and audit activities and documentation. Letter grading.

202. Reliability, Maintainability, and Supportability. (4) Lecture, four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with one to two years work experience. Integrated logistics 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 relationship to the ILS function. Topics include fault detection and isolation and performance. Discussion of 6-sigma process, one effective design and manufacturing methodology, to ensure system reliability, maintainability, and supportability. Letter grading. Mr. Lynch, Mr. Wesel.

203. System Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course 201. Designed for graduate students with BS degrees in engineering or science and one to two years work experience in selected domain. Art and science of archiecture. Introduction to architecture methodology—paradigm and tools. Principles of architectural analysis through analysis of architecture designs in existing systems. Discussion of selected elements of architectural practices.
models, design progression, and architecture frame- 
works. Apply principles of professional engineering 
and architecture. Letter grading. Mr. Lynch, Mr. Wesel

204. Trusted Systems Engineering. (4) Lecture, 
four hours; outside study, eight 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 in- 
volved more than composing systems from network 
security, computer security, data security, cryptog- 
raphy, etc. One can use most secure components, 
and resulting system could still be vulnerable. Skills 
learned are used to architect systems, to identify 
signed, implemented, tested, and operate for spe- 
cific levels of trust. Aspects include assessing vulner- 
ability 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.

205. Model-Based Systems Engineering. (4) Lec- 
ture, four hours; outside study, eight hours. Model-
based systems engineering (MBSE) and systems 
modeling language (SysML) taught through lectures 
and in-class projects, and group project. Lectures 
readings and to provide students with conceptual framework and vocabulary. Indi-
vidual projects enable students to develop basic skills for creating SysML requirements and structural and behavior diagrams, with emphasis on mastery of Excel spreadsheet modeling as integral part of analytic decision making. Managerial models include data modeling, regression and fore-
casting, linear programming, network and distribution models, integer programming, nonlinear program-
m ing, and Monte Carlo simulation. Problems from operations, finance, and marketing taught by spreadsheet computer algebra, and present general managerial sit-
uations from various industries and disciplines. De-
velopment of spreadsheet models to facilitate deci-
sion making. Letter grading. Mr. Mosleh (W)

210. Operations and Supply Chain Management. (4) 
Lecture, four hours; outside study, eight hours. Recom-
manded prerequisites: course 204, Computer Science 256. Systems are constructed to perform complex functions and services. How to understand needs of users, analysis of requirements and derived require-
ments, creation of various system architecture prod-
ucts, and design and integration of various compo-
nents into systems that perform these functions and services. System assurance addresses confidence that systems meet specified operational require-
ments based on evidence provided by applying as-
surance techniques. Production, design, testing, and 
analysis of framework of assurance to accomplish total system assurance. Development of secure, reli-
able, and dependable systems that range from com-
mercial realm such as air traffic control, Supervisory Control and Data Acquisition (SCADA), and autono-
mous vehicles to military realm such as command, 
control, communication, intelligence, and cyber. 
Letter grading.

211. Financial Management. (4) Lecture, four hours; 
outside study, eight hours. Introduction to concepts 
reflecting general material covered in certain MBA 
courses. Integration of financial theory—introduce 
elemental essential conceptual building blocks in 
accounting and finance—and empirical practice—
to emphasize how these theories are actu-
ally implemented in real world. Cases, comprehen-
sive problems, and cases require students to pro-
vide student with as much hands-on experience in 
applying material presented as possible. Letter 
grading. Mr. J-M. Yang

Lecture, four hours; outside study, eight hours. Prior 
knowledge of legal doctrines or materials not re-
quired. Intellectual property law is not just topic for 
lawyers. Engineers who have design responsibilities 
must understand how legal systems and processes 
stances protect their designs and in other instances 
stands as obstacle to what would otherwise be most efficient design choice. Engineers with management responsibilities, those related to key processes affecting orga-

nizational unit’s performance. Letter grading.

231. Data and Business Analytics. (4) Lecture, 
four hours; outside study, eight hours. Coverage of wide 
variety of spreadsheet models that can be used to 
link, manipulate, and analyze data. Solving problems 
with emphasis on mastery of Excel spreadsheet modeling as integral part of analytic decision making. Managerial models include data modeling, regression and fore-
casting, linear programming, network and distribution models, integer programming, nonlinear program-
m ing, and Monte Carlo simulation. Problems from operations, finance, and marketing taught by spreadsheet computer algebra, and present general managerial sit-
uations from various industries and disciplines. De-
velopment of spreadsheet models to facilitate deci-
sion making. Letter grading. Mr. Mosleh (W)

(3–3–1.5) Lecture, three hours (courses 472A, 
472B, 472C) and 90 minutes (course 472D). Limited to Engineering Executive Program students. Lan-
guage of business for engineering executive. Ac-
counting, finance, business economics, business law, 
and marketing. Laboratory in organization and manage-
ment problem solving. Analysis of actual business prob-
lems of firm, community, and nation, provided through cooperation and participation with California business corporations and government 
agencies. In Progress (472A, 472C) and S/U or letter 
grading (credit will be given on completion of courses 
472B and 472D).

473A-473B. Analysis and Synthesis of Large-
Scale Systems. (3–3–3) Lecture, two and one half 
hours; outside study, six hours. Limited to Engi-
neering Executive Program students. Problem area of 
modern industry or government is selected as class 
project, and its solution is synthesized using quanti-
tative tools and methods. Project also serves as labo-
atory in organization and management. Letter 
grading.

495A. Teaching Assistant Training Seminar. (4) 
Seminar, four hours; outside study, eight hours. Preparation: appointment as teaching assistant. Lim-
ited to graduate engineering students. Seminar on 
communication of engineering principles, concepts, 
and methods, preparation, organization of material, 
presentation, use of visual aids, grading, advising, 
and rapport with students. S/U grading.

M495S, Teaching Preparation Seminar: Writing for 
Engineers. (4) (Formerly numbered M495SB.) (Same 
as English Composition M495S.) Seminar, two and 
one half hours; outside study, nine and one half 
hours. Limited to graduate students. Required of all 
teaching assistants for Engineering writing courses not exempt by appropriate departmental or program 
training. Training and mentoring, with focus on com-
position pedagogy, assessment of student writing, 
guidance of revision process, and specialized writing 
problems that may occur in engineering writing con-
texts. Practical concerns of preparing students to 
write course assignments, marking and grading 
pronunces, and conducting peer reviews and conferences. S/U grading. (F,W,Sp)

501. Cooperative Program. (2 to 8) Tutorial, to be 
arranged. Preparation: apprentice or fellow. Teaching 
apprenticeship under active guidance of mentor or fellow. Tutorial, to be

Schoolwide Programs, Courses, and Faculty / 127
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. The CDSC team originally consisted of researchers from four universities: UCLA (lead institution), Rice University, UC Santa Barbara, and Ohio State University. Oregon Health and Science University joined as a research partner under the InTrans program. 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 offers summer research fellowship programs for high school and undergraduate students.

CDSC was originally funded by the National Science Foundation with a $10 million award from the 2009 Expeditions in Computing program, which was among the largest single investments made by the NSF Computer and Information Science and Engineering (CISE) Directorate. In July 2014, CDSC was awarded an additional $3 million by Intel Corporation with matching support from NSF under its Innovation Transition (InTrans) program. This award supports follow-on research on accelerator-rich architectures with applications to health care, in which personalized cancer treatment was added as an application domain in addition to medical imaging. Currently, CDSC has a number of industrial sponsors worldwide including Baidu, Falcon Computing Solutions, Fujitsu, Google, Huawei, Mentor Graphics, and Intel.

Center for Encrypted Functionalities

National Science Foundation (NSF) Secure and Trustworthy Cyberspace FRONTIER Award

Amit Sahai, Ph.D. (Computer Science), Director; http://web.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 Translational Applications of Nanoscale Multiferroic Systems

National Science Foundation (NSF) 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-erc.org

The Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) is a 10-year program focused on miniaturizing electromagnetic devices using a three-pillar strategy involving research, translation, and education. The research strategy engages the best researchers from the six TANMS campuses (UCLA, UC Berkeley, Cornell University, California State University, Northridge, Northeastern University, and University of Texas at Dallas) to understand and develop new nanoscale multiferroic devices. 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, graduate, undergraduate, and K-12 students that also help educate the next generation of engineering leaders. TANMS promotes an inclusive atmosphere, producing a more innovative and diverse research environment compared to monolithic center cultures.

Center for Excellence for Green Nanotechnologies

Kang L. Wang, Ph.D. (Electrical and Computer Engineering), Director

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 Abdulaziz City for Science and Technology (KACST) in Saudi Arabia and UCLA Samuel collaborate in CEGN under KACST's established Joint Center of Excellence Pro-
KACST has an agreement with UCLA for technology transfer and research exchanges. CEGN was awarded an additional $11 million through 2020 in its recent renewal effort, expanding on the work that was originally funded at $3.7 million.

**Named Data Networking Project**

National Science Foundation (NSF) 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, develops technology, creates innovations, and demonstrates advanced technologies to enable the development of the next generation of the electric utility grid—the smart grid. SMERC is currently working on electric vehicle-to-grid integration (V1G and V2G), microgrids, distributed renewable integration including solar and wind, energy storage integration within microgrids, autonomous electric vehicles, distributed energy resources, automated demand response, cybersecurity, and consumer behavior. SMERC also enhances thought leadership through partnership between utilities, renewable energy companies, technology providers, electric vehicle and electric appliance manufacturers, DOE research labs, and universities, as so to collectively work on vision, planning, and execution towards a grid of the future. The partnership recently launched the Energy for a Smart Grid (ESmart) Industry Consortium. It is expected that this smart grid would enable integration of renewable energy sources, allow for integration of electric vehicles and energy storage, improve grid efficiency and resilience, reduce power outages, allow for competitive energy pricing, and overall become more responsive to market, consumer, and societal needs. SMERC is a participant in the Los Angeles Department of Water and Power (LADWP) Regional Smart Grid Demonstration Project, which has been funded by DOE at an estimated $60 million for LADWP and its partners combined. The SMERC microgrid demonstration project is funded by the California Energy Commission.

**Synthetic Control Across Length-scales for Advancing Rechargeables Center**

Department of Energy (DOE) Energy Frontier Research Center

Sarah Tolbert, Ph.D. (Chemistry and Biochemistry, Materials Science and Engineering), Director

The UCLA-led Synthetic Control Across Length-scales for Advancing Rechargeables Center (SCALAR) helps accelerate research on new types of chemistry and materials for rechargeable batteries. Researchers seek to increase battery capacity, stability, and safety.

**WIN Institute of Neurotronics**

Nanoelectronics Research Initiative National Institute of Excellence

Kang L. Wang, Ph.D. (Electrical and Computer 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**

Benjamin M. Wu, D.D.S, Ph.D. (Biomechanics), Director; Bruce Dobkin, M.D. (Medicine/Neurology), William Kaiser, Ph.D. (Electrical and Computer Engineering), Gregory J. Pottie, Ph.D. (Electrical and Computer Engineering), Co-Directors

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 wireless mobile-health technologies can serve as monitoring devices of health and activity, provide feedback to train more healthy behaviors and lessen risk factors for stroke and heart disease, and offer novel 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 the Internet and Wi-Fi transmission using telephones and other convenient devices. To pursue these applications, WHI collaborators include the highly ranked UCLA
WHI strategies and products appear in diverse health care scenarios including motion sensing of the type, quantity, and quality of exercise and practice in disabled persons; prevention of pressure sores; recovery after orthopaedic procedures; assessment of the recovery of bowel motility after surgery; monitoring cardiac output and predicting an exacerbation of heart failure; advancing athletic performance; and others. UCLA and international clinical trials, funded by the National Institutes of Health and American Heart Association, have validated motion pattern recognition and sensor feedback to increase walking and exercise after stroke. Several WHI products developed by the UCLA team are now in the marketplace in the U.S. and Europe. WHI welcomes new team members and continuously forms new collaborations with colleagues and organizations in engineering, medical science, and health care delivery.
# B.S. in Aerospace Engineering

## Aeronautics Track Curriculum

### FRESHMAN YEAR

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<tr>
<th>Quarter</th>
<th>Course</th>
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<td>1st</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A—Differential and Integral Calculus&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Mechanical and Aerospace Engineering 1—Undergraduate Seminar&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Mathematics 31B—Integration and Infinite Series&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Physics 1A—Mechanics&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Mathematics 32A—Calculation of Several Variables&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory&lt;sup&gt;1&lt;/sup&gt;</td>
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### SOPHOMORE YEAR

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<td>Mathematics 33A—Linear Algebra and Applications&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics&lt;sup&gt;2&lt;/sup&gt;</td>
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### JUNIOR YEAR

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<tr>
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<td>Mechanical and Aerospace Engineering 150A—Intermediate Fluid Mechanics&lt;sup&gt;2&lt;/sup&gt;</td>
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### SENIOR YEAR

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### TOTAL

180

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See page 108 for list of electives.
# B.S. in Aerospace Engineering

## Space Track Curriculum

### FRESHMAN YEAR

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<tr>
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<tr>
<td><strong>1st Quarter</strong></td>
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<td>Mathematics 32A—Calculus of Several Variables¹</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory¹</td>
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<td>Mathematics 32B—Calculus of Several Variables¹</td>
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<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory¹</td>
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### SOPHOMORE YEAR

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<td></td>
<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials²</td>
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<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics²</td>
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<td>Mechanical and Aerospace Engineering M20 [Introduction to Computer Programming with MATLAB] or Computer Science 31[Introduction to Computer Science]²</td>
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<td>Mechanical and Aerospace Engineering 82—Mathematics of Engineering²</td>
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### JUNIOR YEAR

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<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems²</td>
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<td>Mechanical and Aerospace Engineering 150A—Intermediate Fluid Mechanics²</td>
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<td>HSSEAS GE Elective³</td>
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<td>Mechanical and Aerospace Engineering 150B (Aerodynamics) or C150P (Aircraft Propulsion Systems)²</td>
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<td>Mechanical and Aerospace Engineering C150R—Rocket Propulsion Systems²</td>
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### SENIOR YEAR

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<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory²</td>
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<td>Mechanical and Aerospace Engineering 161A—Introduction to Astronautics²</td>
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<tr>
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<tr>
<td><strong>3rd Quarter</strong></td>
<td>Mechanical and Aerospace Engineering 157A—Fluid Mechanics and Aerodynamics Laboratory²</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 161C—Spacecraft Design²</td>
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**TOTAL**                                                      | 180   |

1. Counts as Mathematics and Basic Sciences for ABET; total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See page 107 for list of electives.
**B.S. in Bioengineering Curriculum**

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<td>Bioengineering 10—Introduction to Bioengineering</td>
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<tr>
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<td>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
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<tr>
<td>Physics 1B/1AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Bioengineering 100—Bioengineering Fundamentals</td>
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<td>Chemistry and Biochemistry 30B—Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<td>Chemistry and Biochemistry 30AL—General Chemistry Laboratory II</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 7C—Physiology and Human Biology</td>
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<td><strong>1st Quarter</strong></td>
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<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<td>Bioengineering 110—Biotransport and Bioreaction Processes</td>
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<td><strong>SENIOR YEAR</strong></td>
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<td><strong>1st Quarter</strong></td>
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<td>Bioengineering 177A—Bioengineering Capstone Design I</td>
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<td><strong>2nd Quarter</strong></td>
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<td>Bioengineering 177B—Bioengineering Capstone Design II</td>
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<td>Bioengineering 180—System Integration in Biology, Engineering, and Medicine</td>
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<td><strong>3rd Quarter</strong></td>
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<td>Bioengineering Electives (2)</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 74.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
5. Restricted electives include Bioengineering C101, C106, C131, C155, M260 (a petition is required for M260).
### B.S. in Chemical Engineering

#### Chemical Engineering Core Option Curriculum

#### FRESHMAN YEAR

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<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<td>English Composition 3 — English Composition, Rhetoric, and Language</td>
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#### 2nd Quarter

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<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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#### 3rd Quarter

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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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#### SOPHOMORE YEAR

#### 1st Quarter

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<td>Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering</td>
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<tr>
<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory II</td>
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<tr>
<td>Mathematics 32B — Calculus of Several Variables</td>
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#### 2nd Quarter

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#### JUNIOR YEAR

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#### TOTAL

| Units                                                                 | 180   |

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#### Biomedical Engineering Option Curriculum

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**TOTAL** | 180 |

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# B.S. in Chemical Engineering

## Biomolecular Engineering Option Curriculum

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**TOTAL** ................................................................. 180

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#### Environmental Engineering Option Curriculum

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<td>Technical Breadth Course</td>
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<tr>
<td><strong>TOTAL</strong></td>
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</table>

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
# B.S. in Chemical Engineering

## Semiconductor Manufacturing Engineering Option Curriculum

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>UNITS</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering</td>
</tr>
<tr>
<td></td>
<td>Chemistry and Biochemistry 20A — Chemical Structure</td>
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<tr>
<td></td>
<td>Mathematics 31A — Differential and Integral Calculus</td>
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<tr>
<td>2nd Quarter</td>
<td>Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change</td>
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<tr>
<td></td>
<td>Mathematics 31B — Integration and Infinite Series</td>
</tr>
<tr>
<td></td>
<td>Physics 1A — Mechanics</td>
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<tr>
<td>3rd Quarter</td>
<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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<tr>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<tr>
<td></td>
<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering</td>
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<td>Chemistry and Biochemistry 30AL — General Chemistry Laboratory II</td>
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<td>Physics 1C — Electrodynamics, Optics, and Special Relativity</td>
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<td>Chemical Engineering 45 — Biomolecular Engineering Fundamentals</td>
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<tr>
<td></td>
<td>Chemical Engineering 102A — Thermodynamics</td>
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<td>Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>3rd Quarter</td>
<td>Chemical Engineering 102B — Thermodynamics II</td>
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<td>Civil and Environmental Engineering M20 — Introduction to Computer Programming with MATLAB</td>
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<td>Mathematics 33B — Differential Equations</td>
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<th>JUNIOR YEAR</th>
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<tbody>
<tr>
<td>1st Quarter</td>
<td>Chemical Engineering 101A — Transport Phenomena</td>
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<tr>
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<td>Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101B — Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 101C — Mass Transfer</td>
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<td>Chemical Engineering 103 — Separation Processes</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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<tr>
<td>3rd Quarter</td>
<td>Chemical Engineering 104C/104CL — Semiconductor Processing/Laboratory</td>
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<td>Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis</td>
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<td>Chemical Engineering C116 — Surface and Interface Engineering</td>
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**TOTAL**: 180

---

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
# B.S. in Civil Engineering Curriculum

## FRESHMAN YEAR

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<td>Mathematics 31A—Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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## SOPHOMORE YEAR

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<td>Civil and Environmental Engineering 91—Statics</td>
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<td>Civil and Environmental Engineering 102—Dynamics of Particles and Bodies</td>
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<td>Civil and Environmental Engineering C104 (Structure, Processing, and Properties of Civil Engineering Materials) or Materials Science and Engineering 104 (Science of Engineering Materials)</td>
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<td>Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids</td>
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<td>Mathematics 33A—Linear Algebra and Applications</td>
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<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>
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<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics</td>
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## JUNIOR YEAR

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<td>Civil and Environmental Engineering 135A—Elementary Structural Analysis</td>
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<td>Civil and Environmental Engineering 150—Introduction to Hydrology</td>
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<td>Civil and Environmental Engineering 153—Introduction to Environmental Engineering Science</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 103—Applied Numerical Computing and Modeling in Civil and Environmental Engineering</td>
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<td>Civil and Environmental Engineering 110—Introduction to Probability and Statistics for Engineers</td>
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## SENIOR YEAR

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<td>2nd Quarter</td>
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<td>Major Field Electives (2)</td>
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<td>3rd Quarter</td>
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<td>Major Field Elective</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 56.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. Must include required courses for two of the major field areas listed on page 50.
## B.S. in Computer Engineering Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Details</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Computer Science 1 (Freshman Computer Science Seminar) or Electrical and Computer Engineering 1 (Undergraduate Seminar)</td>
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<td>Computer Science 31—Introduction to Computer Science I</td>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<td>Mathematics 31A—Differential and Integral Calculus</td>
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<tr>
<td>2nd</td>
<td>Computer Science 32—Introduction to Computer Science II</td>
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<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td>3rd</td>
<td>Computer Science 33—Introduction to Computer Organization</td>
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<td>Engineering 96C—Introduction to Engineering Design: Internet of Things</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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### SOPHOMORE YEAR

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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Mathematics 33A—Linear Algebra and Applications</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<td>2nd</td>
<td>Computer Science 35L—Software Construction Laboratory</td>
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<td>Computer Science M51A or Electrical and Computer Engineering M16—Logic Design of Digital Systems</td>
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<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<td>Mathematics 33B—Differential Equations</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals</td>
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<td>Mathematics 61—Introduction to Discrete Structures</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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### JUNIOR YEAR

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<tr>
<th>Quarter</th>
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<td>Computer Science 118 (Computer Network Fundamentals) or Electrical and Computer Engineering 132B (Data Communications and Telecommunication Networks)</td>
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<td>Computer Science M152A or Electrical and Computer Engineering M116L—Introductory Digital Design Laboratory</td>
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<td>Computer Science 180—Introduction to Algorithms and Complexity</td>
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<td>Electrical and Computer Engineering 115C—Digital Electronic Circuits</td>
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<td>Computer Science M151B or Electrical and Computer Engineering M116C—Computer Systems Architecture</td>
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<td>Electrical and Computer Engineering Elective</td>
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### SENIOR YEAR

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<td>Technical Breadth Course</td>
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<td>Computer Science Elective</td>
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<td>Electrical and Computer Engineering Design Course</td>
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<td>Technical Breadth Course</td>
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<td>Electrical and Computer Engineering Design Course</td>
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### TOTAL

180

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See page 64 or 83 for list of electives.
### B.S. in Computer Science Curriculum

#### FRESHMAN YEAR

<table>
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<tr>
<th>Quarter</th>
<th>Course</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>1st Quarter</td>
<td>Computer Science 1 — Freshman Computer Science Seminar</td>
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<td>Computer Science 31 — Introduction to Computer Science II</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>2nd Quarter</td>
<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>3rd Quarter</td>
<td>Computer Science 33 — Introduction to Computer Organization</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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#### SOPHOMORE YEAR

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<td>Computer Systems Architecture</td>
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<td>Mathematics 33A — Linear Algebra and Applications</td>
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#### JUNIOR YEAR

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<tbody>
<tr>
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<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata</td>
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#### SENIOR YEAR

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See page 63 for list of electives.
5. Any excess or available units not already applied to another degree requirement will satisfy these units.
# B.S. in Computer Science and Engineering Curriculum

## FRESHMAN YEAR

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<td>Computer Science 1 — Freshman Computer Science Seminar</td>
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<td>Mathematics 31A — Differential and Integral Calculus</td>
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<td>Computer Science 32 — Introduction to Computer Science II</td>
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<td>Mathematics 31B — Integration and Infinite Series</td>
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<td>Physics 1A — Mechanics</td>
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<td>Computer Science 33 — Introduction to Computer Organization</td>
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<td>Mathematics 32A — Calculus of Several Variables</td>
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<td>Physics 1B — Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

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<td>Mathematics 33A — Linear Algebra and Applications</td>
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<td>Mathematics 61 — Introduction to Discrete Structures</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<td>3rd</td>
<td>Computer Science 180 — Introduction to Algorithms and Complexity</td>
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<td>Electrical and Computer Engineering 3 — Introduction to Electrical Engineering</td>
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<td>Mathematics 33B — Differential Equations</td>
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## JUNIOR YEAR

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<td>Computer Science 111 — Operating Systems Principles</td>
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<td>Electrical and Computer Engineering 100 — Electrical and Electronic Circuits</td>
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<td>Computer Science 131 — Programming Languages</td>
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<td>Electrical and Computer Engineering 102 — Systems and Signals</td>
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<td>Computer Science 118 — Computer Network Fundamentals</td>
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<td>Computer Science M151B or Electrical and Computer Engineering M116C — Computer Systems Architecture</td>
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## SENIOR YEAR

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<tr>
<td>1st</td>
<td>Computer Science 152B — Digital Design Project Laboratory</td>
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<td>Computer Science 181 — Introduction to Formal Languages and Automata Theory</td>
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<td>Computer Science Elective</td>
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<td>Computer Science Elective</td>
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**TOTAL** | | | **180**

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 49.
3. Students should consult the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See page 62 for list of electives.
5. Any excess or available units not already applied to another degree requirement will satisfy this unit.
B.S. in Electrical Engineering Curriculum

FRESHMAN YEAR

1st Quarter
Computer Science 31—Introduction to Computer Science 2
English Composition 3—English Composition, Rhetoric, and Language ........................................... 4
Mathematics 31A—Differential and Integral Calculus 3 ............................................................... 5

2nd Quarter
Chemistry and Biochemistry 20A—Chemical Structure 1 ............................................................ 4
Computer Science 32—Introduction to Computer Science II 2 ...................................................... 4
Mathematics 31B—Integration and Infinite Series 1 ................................................................. 4
Physics 1A—Mechanics 1 ........................................................................................................... 5

3rd Quarter
Electrical and Computer Engineering M16 (or Computer Science M51A)—Logic Design of Digital Systems 2 .......................................................... 4
Mathematics 32A—Calculus of Several Variables 1 .................................................................. 4
Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory 1 ............... 7

SOPHOMORE YEAR

1st Quarter
Electrical and Computer Engineering 3—Introduction to Electrical Engineering 2 ......................... 4
Mathematics 32B—Calculus of Several Variables 1 .................................................................. 4
Mathematics 33A—Linear Algebra and Applications 1 .................................................................. 4
Physics 1C—Electrodynamics, Optics, and Special Relativity 1 .................................................. 5

2nd Quarter
Electrical and Computer Engineering 10 (Circuit Theory I) and 11L (Circuits Laboratory I) 2 .............. 5
Electrical and Computer Engineering 102—Systems and Signals 2 ............................................. 4
Mathematics 33B—Differential Equations 1 .................................................................................. 4
Physics 4BL—Electricity and Magnetism Laboratory 1 ................................................................ 2

3rd Quarter
Electrical and Computer Engineering 2—Physics for Electrical Engineers 2 .............................. 4
Electrical and Computer Engineering 110 (Circuit Theory II) and 111L (Circuits Laboratory II) 2 .............. 6
HSSEAS Ethics Course .............................................................................................................. 4
HSSEAS GE Elective 3 .............................................................................................................. 4

JUNIOR YEAR

1st Quarter
Electrical and Computer Engineering 113—Digital Signal Processing 2 ........................................... 4
Electrical and Computer Engineering 131A—Probability and Statistics 2 ......................................... 4
HSSEAS GE Elective 3 .............................................................................................................. 5

2nd Quarter
Electrical and Computer Engineering 101A—Engineering Electromagnetics 2 ................................. 4
Electrical and Computer Engineering Core Course 2, 4 .................................................................. 4
HSSEAS GE Elective 3 .............................................................................................................. 5

3rd Quarter
Electrical and Computer Engineering Core Course 2, 4 .................................................................. 4
Electrical and Computer Engineering Core Course 2, 4 .................................................................. 4
Electrical and Computer Engineering Core Course 2, 4 .................................................................. 4
Electrical and Computer Engineering Core Course or Computer Science 33 (Introduction to Computer Organization) 2, 4 .................................................. 4

SENIOR YEAR

1st Quarter
Electrical and Computer Engineering Core Course 2, 4 .................................................................. 4
Electrical and Computer Engineering Design Course 2 .................................................................. 4
Electrical and Computer Engineering Elective 3 ........................................................................... 4
Technical Breadth Course 3 ........................................................................................................... 4

2nd Quarter
Electrical and Computer Engineering Design Course 2 .................................................................. 4
Electrical and Computer Engineering Elective 2 ........................................................................... 4
HSSEAS GE Elective 3 .............................................................................................................. 5
Technical Breadth Course 3 ........................................................................................................... 4

3rd Quarter
Electrical and Computer Engineering or HSSEAS Elective 2 .......................................................... 4
HSSEAS GE Elective 3 .............................................................................................................. 5
Technical Breadth Course 3 ........................................................................................................... 4

TOTAL ........................................................................................................................................ 162

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 47.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See page 82 for list of core courses.
## B.S. in Materials Engineering Curriculum

### Materials Engineering Option Curriculum

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<thead>
<tr>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory1</td>
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<td><strong>1st Quarter</strong></td>
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<td>Civil and Environmental Engineering 101 (Statics) or Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)2</td>
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<td>Materials Science and Engineering 104—Science of Engineering Materials2</td>
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<td>Mathematics 32B—Calculus of Several Variables1</td>
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<td><strong>2nd Quarter</strong></td>
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<td>Materials Science and Engineering 90L—Physical Measurement in Materials Engineering2</td>
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<td>Physics 1C—Electrodynamics, Optics, and Special Relativity1</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)2</td>
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<td>Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)1</td>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory2</td>
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<td>Materials Science and Engineering 130—Phase Relations in Solids2</td>
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<td>Materials Science and Engineering 120—Physics of Materials2</td>
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<td>Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory2</td>
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<td>Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids2</td>
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<td>Materials Science and Engineering 132—Structures and Properties of Metallic Alloys2</td>
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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits2</td>
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<td>Materials Science and Engineering 160—Introduction to Ceramics and Glasses2</td>
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<td>Materials Science and Engineering 140—Materials Selection and Engineering Design2</td>
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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 54.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 100 for list of approved mathematics courses.
6. Any excess or available units not already applied to another degree requirement will satisfy these units.
# B.S. in Materials Engineering

## Electronic Materials Option Curriculum

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<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Chemistry and Biochemistry 20A—Chemical Structure(^1)</td>
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<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory(^1)</td>
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<td>Mathematics 31B—Integration and Infinite Series(^1)</td>
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<td>Mathematics 32A—Calculus of Several Variables(^1)</td>
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<tr>
<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields(^1)</td>
<td>5</td>
</tr>
<tr>
<td>HSSEAS GE Elective(^3)</td>
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</tr>
</tbody>
</table>

## SOPHOMORE YEAR

| **1st Quarter** |       |
| Materials Science and Engineering 104—Science of Engineering Materials\(^2\) | 4 |
| Mathematics 32B—Calculus of Several Variables\(^1\) | 4 |
| HSSEAS GE Elective\(^3\) | 5 |
| **2nd Quarter** |       |
| Materials Science and Engineering 90L—Physical Measurement in Materials Engineering\(^2\) | 2 |
| Mathematics 33A—Linear Algebra and Applications\(^1\) | 4 |
| Physics 1C—Electrodynamics, Optics, and Special Relativity\(^1\) | 4 |
| HSSEAS GE Elective\(^3\) | 4 |
| **3rd Quarter** |       |
| Civil and Environmental Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science)\(^2\) | 4 |
| Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)\(^1\) | 4 |
| Mechanical and Aerospace Engineering 101—Statics and Strength of Materials\(^2\) | 4 |
| HSSEAS Ethics Course | 4 |

## JUNIOR YEAR

| **1st Quarter** |       |
| Electrical and Computer Engineering 100—Electrical and Electronic Circuits\(^2\) | 4 |
| Materials Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory\(^2\) | 6 |
| Materials Science and Engineering 130—Phase Relations in Solids\(^2\) | 4 |
| HSSEAS GE Elective\(^3\) | 5 |
| **2nd Quarter** |       |
| Electrical and Computer Engineering 101A—Engineering Electromagnetics\(^2\) | 4 |
| Materials Science and Engineering 120 (Physics of Materials) or Electrical and Computer Engineering Electrical and Computer Engineering 2 (Physics for Electrical Engineers)\(^2\) | 4 |
| Materials Science and Engineering 122—Principles of Electronic Materials Processing\(^2\) | 4 |
| Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory\(^2\) | 6 |
| **3rd Quarter** |       |
| Materials Science and Engineering 121/121L—Materials Science of Semiconductors/Laboratory\(^2\) | 6 |
| Materials Science and Engineering 132—Structures and Properties of Metallic Alloys\(^2\) | 4 |
| Electronic Materials Elective (Materials Science and Engineering 150—Introduction to Polymers or 160—Introduction to Ceramics and Glasses)\(^2,4\) | 4 |
| Technical Breadth Course\(^3\) | 4 |

## SENIOR YEAR

| **1st Quarter** |       |
| Electrical and Computer Engineering 121B—Principles of Semiconductor Device Design\(^2\) | 4 |
| Upper-Division Mathematics Course\(^1,5\) | 4 |
| Technical Breadth Course\(^3\) | 4 |
| **2nd Quarter** |       |
| Electronic Materials Elective\(^2,4\) | 4 |
| Electronic Materials Laboratory Course\(^2,4\) | 4 |
| HSSEAS GE Elective\(^3\) | 2 |
| Technical Breadth Course\(^3\) | 5 |
| **3rd Quarter** |       |
| Materials Science and Engineering 140—Materials Selection and Engineering Design\(^2\) | 4 |
| Electronic Materials Elective\(^2,4\) | 4 |
| Electronic Materials Laboratory Course\(^2,4\) | 4 |

**TOTAL** 180

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1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 54.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 100 for list of approved mathematics courses.
### B.S. in Mechanical Engineering Curriculum

<table>
<thead>
<tr>
<th>Freshman Year</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quarter</strong></td>
<td></td>
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<tr>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
<td>4</td>
</tr>
<tr>
<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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</tr>
<tr>
<td>Mathematics 31A—Differential and Integral Calculus</td>
<td>4</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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</tr>
<tr>
<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
<td>7</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series</td>
<td>4</td>
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<tr>
<td>Physics 1A—Mechanics</td>
<td>5</td>
</tr>
<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
<td>4</td>
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<tr>
<td>Physics 1B/4BL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td><strong>Sophomore Year</strong></td>
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<tr>
<td>Mathematics 32B—Calculus of Several Variables</td>
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<tr>
<td>Mechanical and Aerospace Engineering 94—Introduction to Computer-Aided Design and Drafting</td>
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<tr>
<td>Physics 1C/4BL—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory</td>
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</tr>
<tr>
<td>Materials Science and Engineering 104—Science of Engineering Materials</td>
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<tr>
<td>Mathematics 33A—Linear Algebra and Applications</td>
<td>4</td>
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<tr>
<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials</td>
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<tr>
<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Mechanical and Aerospace Engineering M20 (Introduction to Computer Programming with MATLAB) or Computer Science 31 (Introduction to Computer Science I)</td>
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<tr>
<td>Mechanical and Aerospace Engineering 82—Mathematics of Engineering</td>
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<tr>
<td>Mechanical and Aerospace Engineering 102—Dynamics of Particles and Rigid Bodies</td>
<td>4</td>
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<tr>
<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics</td>
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<tr>
<td><strong>Junior Year</strong></td>
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<tr>
<td><strong>1st Quarter</strong></td>
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<tr>
<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<tr>
<td>Mechanical and Aerospace Engineering 105D—Transport Phenomena</td>
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<tr>
<td>Mechanical and Aerospace Engineering 183A (Introduction to Manufacturing Processes) or M183B (Introduction to Microscale and Nanoscale Manufacturing)</td>
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<td>HSSEAS GE Elective</td>
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<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems</td>
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<tr>
<td>Mechanical and Aerospace Engineering 156A—Advanced Strength of Materials</td>
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<td>Technical Breadth Course</td>
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<tr>
<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics)</td>
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<tr>
<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory</td>
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<tr>
<td>Mechanical and Aerospace Engineering 162A—Introduction to Mechanisms and Mechanical Systems</td>
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<td>HSSEAS GE Elective</td>
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<tr>
<td><strong>Senior Year</strong></td>
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<tr>
<td>Electrical and Computer Engineering 110L—Circuit Measurements Laboratory</td>
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<tr>
<td>Mechanical and Aerospace Engineering 171A—Introduction to Feedback and Control Systems</td>
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<tr>
<td>Technical Breadth Course</td>
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<tr>
<td><strong>2nd Quarter</strong></td>
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<tr>
<td>Mechanical and Aerospace Engineering 162D—Mechanical Engineering Design I</td>
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<td>Mechanical Engineering Elective</td>
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<td>Technical Breadth Course</td>
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<td><strong>3rd Quarter</strong></td>
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<tr>
<td>Mechanical and Aerospace Engineering 162E—Mechanical Engineering Design II</td>
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<tr>
<td>Mechanical Engineering Elective</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td>181</td>
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</tbody>
</table>

1. Counts as Mathematics and Basic Sciences for ABET, total units Mathematics and Basic Sciences = 50.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see page 22 for details).
G

general education requirements, 22
glass and ceramics research laboratories, 102
grade disputes, 16
grading policy, 16
grants, 12
graphics and vision laboratories, 69

H

harassment, 17
health center, 10
Ho systems laboratory, 112
honorary societies, 15
honors
dean’s honors list, 24
latin honors, 24
Hu research laboratory (H-lab), 112
hypersonics and computational aero-
dynamics group, 112

I

information and data management group, 69
information and data management laboratories, 69
institutes, externally funded, 128
international students, 10
Internet research laboratory, 69

L

laboratory for advanced system research (LASR), 70
laboratory for the chemistry of construction materials (LC5), 54
laboratory for the physics of amorphous and inorganic soils (PARISlab), 54
large-scale structure test facility, 54
laser laboratory, 87
laser spectroscopy and gas dynamics laboratory, 112
library facilities
science and engineering library (SEL), 9
university library system, 9
living accommodations, 11
loans, 12

M

M’Closkey laboratory, 112
master of science in engineering online programs, 122
graduate study, 122
materials and plasma chemistry laboratory, 43
materials degradation characterization laboratory, 112
materials engineering curriculum, 144
materials in extreme environments laboratory (MATRIX), 112
materials science and engineering department, 99
bachelor of science degree, 99
course descriptions, 102
curriculum, 144–145
facilities, 101
faculty areas of thesis guidance, 102
fields of study, 101
graduate study, 100
mechanical and aerospace engineering department, 106
aerospace engineering curriculum, 131, 132
bachelor of science degrees, 107
centers, facilities, and laboratories, 110
course descriptions, 115
faculty areas of thesis guidance, 114
fields of study, 110
graduate study, 108
mechanical engineering curriculum, 146
mechanical testing laboratory, 102
mechanical vibrations laboratory, 53
mechanics of soft materials laboratory, 112
mechatronics and controls laboratory, 112
MESA schools program, 13
metallographic sample preparation laboratory, 102
micro- and nano-manufacturing laboratory, 112
micro-manufacturing laboratory, 112
modeling of complex thermal systems laboratory, 112
Morrin-Gier-Martinelli heat transfer memorial laboratory, 113
multidisciplinary research facilities, 88
multiscale thermosciences laboratory (MTSL), 113

N

named data networking project, 129
nano-electronics research facility, 87
nano-materials laboratory, 102
nanoparticle technology and air quality engineering laboratory, 43
nanoscale transport research group, 113
national science foundation (NSF), 4, 13, 70, 128
national society of black engineers, 14
network research laboratory, 70
network systems laboratories, 69
nondestructive testing laboratory, 102
nondiscrimination, 16

O

official publications, 16
online master of science in engineering, 122
optical metrology laboratory, 54
optofluidics systems laboratory, 113
organic electronic materials processing laboratory, 102

P

photons and optoelectronics laboratories, 87
Pilon research group, 113
plasma and beam assisted manufacturing laboratory, 113
plasma and space propulsion laboratory, 113
plasma electronics facilities, 87
polymer and separations research laboratory, 43
precollege outreach programs, 13
prizes and awards, 15
process systems engineering laboratory, 43
reinforced concrete laboratory, 54
research centers, externally funded, 128
research intensive series in engineering for underrepresented populations (RISE-UP), 14
robotics and mechanisms laboratory, 113
scalable analytics institute (ScAI), 70
scholarship requirement, 21
scholarships, 11, 14
school requirements, 21
schoolwide programs and courses, 125
course descriptions, 125
graduate study, 125
scifacturing laboratory, 113
semiconductor and optical characterization laboratory, 102
semiconductor manufacturing engineering curriculum, 138
services for students with disabilities, 10
shop services center, 9
simulations of flow physics and acoustics laboratory (SoFiA), 114
smart grid energy research center (SMERC), 113, 129
SMASH precollege program, 13
society of Latino engineers and scientists, 15
software systems group, 70
software systems laboratories, 70
soil mechanics laboratory, 54
solid-state electronics facilities, 87
special programs, activities, and awards, 13
structural design and testing laboratory, 54
student health center, 10
student organizations, 14
student societies, 15
student study center, 14
study list, 23
summer bridge program, 13
synthetic control across length-scales for advancing rechargeable center (SCALAR), 129

teaching assistantships, 12
technical breadth requirement, 22
thermochemical energy storage laboratory, 114
thin film deposition laboratory, 102
thin films, interfaces, composites, characterization laboratory, 114
turbulence research group, 114

U

unit requirement, 21
university requirements, 21

V

VAST laboratory, 69
vision laboratory, UCLA, 69

W

Web information systems laboratory, 69
WIN institute of neurotronics (WINS), 129
wireless health institute (WHI), 70, 88, 129
wireless networking group (WING), 70
women in engineering, 15
work-study programs, 12
writing requirement, 21

X

X-ray diffraction laboratory, 102
X-ray photoelectron spectroscopy and atomic force microscopy facility, 102