UNIVERSITY OF CALIFORNIA, LOS ANGELES
OCTOBER 1, 2020

Bioengineering
Chemical & Biomolecular
Civil & Environmental
Computer Science
Electrical & Computer
Materials Science
Mechanical & Aerospace
Master of Science in Engineering Online
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Published by UCLA Academic Publications, Box 951429, Los Angeles, CA 90095-1429  
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All announcements herein are subject to revision. Every effort has been made to ensure the accuracy of the information presented in the Announcement of the UCLA Henry Samueli School of Engineering and Applied Science.  
However, all courses, course descriptions, instructor designations, curricular degree requirements, and fees described herein are subject to change or deletion without notice. More details on graduate programs are available in various Graduate Division materials online.  
Cover: Engineering students in the UCLA campus Court of Sciences, adjacent to the school’s Boelter Hall, three dedicated engineering buildings, and dozens of surrounding science and technology facilities.
A Message from the Dean

The UCLA Henry Samueli School of Engineering and Applied Science has a long legacy of excellence in education and research. We work on the most pressing problems facing our society: designing sustainable and resilient communities, developing personalized medicine, advancing artificial intelligence, paving the way for quantum technologies, and unearthing insights from big data.

As we enter our 75th year, we welcome a new generation of engineers—with diverse backgrounds from around the world—to join us as we tackle these and many more compelling issues. Engineering change that will improve our world requires not only creativity and skill, but also thoughtfulness and empathy.

UCLA Samueli classes are taught by faculty members who are among the best in the world in their respective fields. We are proud to cultivate students of all backgrounds, who are creative and motivated, and who bring an exemplary work ethic to their studies.

The school offers a rigorous curriculum that pairs strong fundamentals with practical, hands-on experience. Beyond the core curriculum, UCLA Samueli offers three pivotal advantages:

First, UCLA Samueli isn’t just a great school standing in isolation. It is an integral part of one of the world’s most innovative cities, and offers unparalleled access to sought-after internships and careers. Many leading firms in aerospace, semiconductors, biotechnology and other impactful areas are headquartered in Southern California. The region is also home to a major startup scene in which our alumni are involved. In fact, some founded their first startup while at UCLA.

Second, in addition to paving the way to careers in industry, we offer unique research opportunities for our undergraduate students. They play an active role in our labs, with some research earning course credit. The school features a 9,000-square-foot makerspace where students can work on personal projects and hold group activities such as hack-a-thons. Our students also often collaborate with the David Geffen School of Medicine at UCLA and other campus disciplines as they pursue new approaches and breakthroughs.

Third, you will meet some extraordinary people among your fellow students. The talent, smarts, outside-the-box thinking and collaborative, can-do energy at UCLA are unparalleled. If you are interested in exploring fields outside your major, we have more than 44 engineering clubs focused on a wide range of activities. At UCLA Samueli, we are committed to an equitable, diverse, and inclusive culture and we want everyone to feel welcome in our community.

This particular school year presents an unprecedented challenge for all of us, as we continue to adapt to remote instruction due to the COVID-19 pandemic. We are absolutely dedicated to ensuring the very best possible education and learning experience for all our students. I am grateful for our problem-solving engineers who are resilient, resourceful, and compassionate.

Despite the public health crisis, we remain hopeful about our future. UCLA Samueli is in the midst of an extraordinary period of growth, with expansion in the number of research labs, faculty, and students. The school already is world-renowned, but we are reaching for new heights. This growth will offer new opportunities for you to make a significant impact on our society and the world, and 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

Administrative Officers

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, Henry Samueli School of Engineering and Applied Science

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

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

Eliezer M. Gafni, Ph.D., Professor and Chair, Computer Science Department

Song Li, Ph.D., Professor and Chair, Bioengineering Department

Ertugrul Taciroglu, Ph.D., Professor and Chair, Civil and Environmental Engineering Department

C.-K. Ken Yang, Ph.D., Professor and Chair, Electrical and Computer Engineering Department

The Campus

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

UCLA is recognized as the West’s leading center for the arts, culture, and medical research. Each year, more than half a million people attend visual and performing arts programs on campus; while more than 380,000 patients from around the world come to the Ronald Reagan UCLA Medical Center for treatment. The University’s 419-acre campus houses the College of Letters and Science and 12 professional schools. There are more than 45,000 students enrolled in 140 undergraduate degree programs, and more than 250 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 UCLA 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 Samuel 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 renamed the Henry Samueli School of Engineering and Applied Science in 2000.

Counted among the faculty are three dozen National Academy of Engineering members, and nearly 80 recipients of the National Science Foundation’s early career award. While no ranking can fully capture the success of a leading public research university, the school is consistently ranked in the top 10 among U.S. public engineering schools, and the online master’s program has consistently been ranked first or second nationally.

The goal of UCLA Samueli is to enable as much positive change as possible through the impact that engineers can have on society. As part of its academic program, the school focuses on research that targets today’s greatest societal challenges, education that empowers students to become future change agents, access for the graduates to succeed in engineering careers, and innovation that helps bring great ideas to the market.

The school has identified six critical areas of research where it can have the greatest positive impact in the years and decades to come. These include robotics and cyber-physical systems; sustainable and resilient urban systems; engineering in medicine; big data, artificial intelligence, and machine learning; cybersecurity and future Internet; and advanced materials and manufacturing.

UCLA Samueli is well known for the research advances its laboratories and alumni have brought to the world. By defining these critical areas of research for the 21st century, the school is able to offer its resources and create a relevant educational structure for its students to galvanize the next generation of global leaders.

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 offer students a solid foundation in engineering and applied science, and prepare graduates for immediate practice of the profession as well as advanced studies. In addition to engineering courses, students complete about one year of study in the humanities, social sciences, or fine arts.

Master of Science and Doctor of Philosophy degrees are offered in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Engineering, Computer Science, Electrical and Computer 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 more advanced than the regular master’s, but does not require the research effort and orientation involved in a doctoral dissertation.

Endowed Chairs

Endowed professorships or chairs, funded by gifts from individuals or corporations, support the research and educational activities of distinguished faculty members. The following endowed chairs have been
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, and advanced materials processing. They are in charge of the chemical processes used by virtually all industries, including the pharmaceutical, conductor 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 waste-water 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 processes, including energy generation, utilization and conservation, power and propulsion systems (power plants, engines), and commercial products found in the automotive, aerospace, chemical, or electronics industries.

The B.S. program in Mechanical Engineering at UCLA provides excellent preparation for a career in mechanical engineering and a foundation for advanced graduate studies. Graduate studies in one of the specialized fields of mechanical engineering prepare students for a career at the forefront of technology. The Ph.D. degree provides a strong background for employment by government laboratories, industrial research laboratories, and academia.

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**Correspondence Directory**

**Henry Samueli School of Engineering and Applied Science**

- **School website**
- **Office of Academic and Student Affairs**
  6426 Boelter Hall
- **Bioengineering Department**
  5121 Engineering V
- **Chemical and Biomolecular Engineering Department**
  5531 Boelter Hall
- **Civil and Environmental Engineering Department**
  5731 Boelter Hall
- **Computer Science Department**
  277 Engineering VI
- **Electrical and Computer Engineering Department**
  58-121 Engineering IV
- **Materials Science and Engineering Department**
  3111 Engineering V
- **Mechanical and Aerospace Engineering Department**
  48-121 Engineering IV
- **Continuing Education in Engineering**
  UCLA Extension
  10960 Wilshire Boulevard, Suite 1600
- **Engineering and Science Career Services**
  UCLA Career Center
  501 Westwood Plaza, Strathmore Building
- **Master of Science in Engineering Online Program**
  4732 Boelter Hall

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**Academic Counselors**

**Aerospace Engineering**
- Anandrea Suarez, 310-825-5146
- Michel Moraga, 310-825-5760
- Jennifer Alvarado, 310-206-2891
- Vanessa Hernandez, 310-825-2757

**Bioengineering**
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- Elizabeth Ceja, 310-206-8712
- Victoria Moraga, 310-825-9602

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- Erkki Corpuz, 310-825-9442
- Jennifer Alvarado, 310-206-2891
- Julietta Torres, 310-206-6397

**Civil Engineering**
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- Jan J. LaBuda, 310-825-2514
- Victoria Moraga, 310-825-9602

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- Mary Anne Geber, 310-825-2036
- Jan J. LaBuda, 310-825-2514
- Victoria Moraga, 310-825-9602

**Electrical and Computer Engineering**
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- Victoria Moraga, 310-825-9602
- Julietta Torres, 310-206-6397

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- Erkki Corpuz, 310-825-9442

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- Anandrea Suarez, 310-825-5146
- Michel Moraga, 310-825-5760
- Jan J. LaBuda, 310-825-2514
- Jennifer Alvarado, 310-206-2891
- Vanessa Hernandez, 310-825-2757

**Undeclared Engineering**
- Erkki Corpuz, 310-825-9442
- Jan J. LaBuda, 310-825-2514

**University of California, Los Angeles**

Los Angeles, California 90095

- **UCLA Website**
- **Undergraduate Admission**
  1147 Murphy Hall
- **Graduate Diversity, Inclusion, and Admissions**
  1248 Murphy Hall
- **Financial Aid and Scholarships**
  A129J Murphy Hall
- **Registrar’s Office**
  1105 Murphy Hall
- **Dashew Center for International Students and Scholars**
  106 Bradley Hall
- **Summer Sessions**
  1332 Murphy Hall

**University of California**

Systemwide Admissions
## Academic Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2020</th>
<th>Winter 2021</th>
<th>Spring 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>First day for continuing students to check MyUCLA</td>
<td>June 1</td>
<td>October 26</td>
<td>January 25</td>
</tr>
<tr>
<td>MyUCLA enrollment appointments begin</td>
<td>June 24</td>
<td>November 9</td>
<td>February 8</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 23</td>
<td>January 2, 2020</td>
<td>March 25</td>
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<tr>
<td>Instruction begins</td>
<td>October 1</td>
<td>January 4</td>
<td>March 29</td>
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<tr>
<td>Last day for undergraduates to add courses with per-course fee</td>
<td>October 23</td>
<td>January 22</td>
<td>April 16</td>
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<tr>
<td>Through MyUCLA</td>
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<tr>
<td>Last day for undergraduates to change grading basis (optional P/NP)</td>
<td>November 13</td>
<td>February 12</td>
<td>May 7</td>
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<td>Through MyUCLA</td>
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<tr>
<td>Last day for undergraduates to drop nonimpacted courses without a</td>
<td>December 4</td>
<td>January 29</td>
<td>April 23</td>
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<td>transcript notation (with per-transaction fee through MyUCLA)</td>
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<tr>
<td>Instruction ends</td>
<td>December 11</td>
<td>March 12</td>
<td>June 4</td>
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<tr>
<td>Final examinations</td>
<td>December 14–18</td>
<td>March 15–19</td>
<td>June 7–11</td>
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<tr>
<td>Quarter ends</td>
<td>December 18</td>
<td>March 19</td>
<td>June 11</td>
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<td>Engineering Commencement</td>
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<td>Academic and administrative holidays</td>
<td>September 7</td>
<td>January 18</td>
<td>March 26</td>
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<td>November 11</td>
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<td>May 31</td>
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<td>November 26-27</td>
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<td>December 24-25</td>
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<td>December 31,</td>
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<td></td>
<td>January 1</td>
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<tr>
<td>Winter campus closure (tentative)</td>
<td>December TBD</td>
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*Dates are subject to change; see UCLA Registrar’s Office website for most current information.*

## Admission Calendar

<table>
<thead>
<tr>
<th>Event</th>
<th>Fall 2020</th>
<th>Winter 2021</th>
<th>Spring 2021</th>
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<tbody>
<tr>
<td>Filing period for undergraduate applications (apply online at</td>
<td>November 1–30,</td>
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<tr>
<td>University of California Admissions – Apply Now)</td>
<td>2019</td>
<td></td>
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<tr>
<td>Last day to file Application for Graduate Admission or</td>
<td>Consult</td>
<td>Consult</td>
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<tr>
<td>readmission with complete credentials and application fee, online</td>
<td>department</td>
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<tr>
<td>or with UCLA Graduate Diversity, Inclusion, and Admissions</td>
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<td>(DIA), 1248 Murphy Hall, Los Angeles, CA 90024-1419</td>
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<tr>
<td>Last day to file Undergraduate Readmission Application</td>
<td>August 15</td>
<td>November 25</td>
<td>February 25</td>
</tr>
<tr>
<td>(late applicants pay a late fee)</td>
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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, undergraduate and graduate instruction, the Office of Academic and Student Affairs, the SEASnet computer facility, 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.

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 SEASnet 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 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 10 lab consultants support the school’s computing needs.

A network of over 158 enterprise servers supply 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-intensive 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 ensures latency-free operation for users from UCLA and around the world. It consists of dual fiber uplinks to a Cisco core router, which feeds and routes 20 networks and over 100 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 Azure Dev Tools for Teaching 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 Azure Dev Tools for Teaching, 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
Digital Technology 310-206-6794
Engineering 310-825-4100

Engineering and Digital Technology Department

Varaz Shahmirian, Ph.D., Director
Vivian Taslakian, M.B.A., Program Director

The UCLA Extension Engineering and Digital Technology department offers one of the nation’s largest selections of engineering continuing 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, data science, database management, coding boot camp, cybersecurity, systems analysis, and Web technology.

The engineering program offers over 250 courses annually, including 10 certificate programs in advanced plumbing systems design, agile project management, biotechnology engineering, communication systems, construction management, contract management, information technology management, government cost estimating and pricing, medical device engineering, project management, recycling and solid waste management, and supply chain management. In addition, the department offers EIT and PE review courses in mechanical engineering. All engineering and technical management courses are offered online.

### Career Services

**UCLA Career Center**

501 Westwood Plaza, Strathmore Building 310-206-1915

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

Services include individual career counseling, career assessments, workshops, industry-specific programming, employer information sessions, career fairs, and targeted networking opportunities. Annual engineering and technical fairs, held in fall and winter quarters, feature more than 100 top national and local employers. Using a Handshake account, students can discover internship and job opportunities, schedule career counseling appointments, access career resources, and register for events.

Career Center drop-in hours (Tuesday through Thursday from 9 a.m. to 2 p.m.) offer support with résumés, cover letters, and the job/internship search process. The center is open Monday through Friday from 9 a.m. to 5 p.m. An engineering-specific pop-up event is held once per quarter in 6288 Boelter Hall.

### Health Services

**Ashe Student Health and Wellness Center**

221 Westwood Plaza 310-825-4073

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 laboratory and radiology sections. It operates the Bruin Health Pharmacy and U See LA Optometry in nearby Ackerman Union. 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 UCHIP or other plans that provide adequate coverage. Adequate medical insurance is a condition of registration. Students who waive UCHIP must 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.

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

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. All incoming students must be vaccinated against or show immunity to multiple infectious diseases consistent with guidelines of the American College Health Association, California Department of Public Health, and U.S. Centers for Disease Control and Prevention (CDC). The Ashe Center website processes students’ proof of immunity prior to enrollment.

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

Nonregistered students (those who withdraw, or are on approved leave or planned academic leave) may have access to UCHIP services under certain conditions.

### Mental Health Services

**Counseling and Psychological Services**

221 Wooden Center West 310-825-0768

Services for mental health range from routine counseling and psychotherapy to crisis counseling. Counseling and Psychological Services (CAPS) offers short-term personal counseling and psychotherapy. Psychologists, clinical social workers, and psychiatrists assist with situational stresses and emotional problems from the most mild to severe. Campus Assault Resources and Education (CARE) counselors provide information, support, and resources concerning assault and domestic violence. Service is confidential.

### Services for Students with Disabilities

**Center for Accessible Education**

A255 Murphy Hall 310-825-1501

The Center for Accessible Education (CAE) offers academic support services to regularly enrolled students with documented permanent or temporary disabilities in compliance with Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, and UC and UCLA policies. Services include campus orientation and accessibility, notetakers, reader service, sign-language interpreters, 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 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.

**Disabilities and Computing Program**

4909 Math Sciences 310-206-7133

The Disabilities and Computing Program (DCP) supplies adaptive technology and information-access support and services to students, faculty, and staff with disabilities. Applications include voice input, Braille, large print, screen-reading software, and learning disability software. Consulting and training for individuals and departments are available. The program also offers Web accessibility evaluations and guidelines.

### International Student Services

**Dashew Center for International Students and Scholars**

106 Bradley International Hall 310-825-1681

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 post-doctoral scholars.

Fees and Financial Support

Fees and Expenses

Annual UCLA student fees shown for 2020-21 are current as of publication. See the Registrar fees web page for fee breakdown by term.

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 for information on how to determine residence for tuition purposes. Inquiries may be directed to the Residence Deputy, UCLA Registrar’s Office, 1113 Murphy Hall, Los Angeles, CA 90024-1429.

In addition to the fees shown, 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

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, and applications for on-campus housing, are available from the UCLA Housing website.

Financial Aid

Financial Aid and Scholarships
A129J Murphy Hall
310-206-0400

Undergraduate Students

Financial aid at UCLA includes scholarships, grants, loans, and work-study programs. 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). Students who are not citizens or permanent residents but who are eligible for Assembly Bill 540 nonresident fee waivers may be eligible to qualify for scholarships, UCLA grant aid, and additional state aid if they complete a California Dream Act application. 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.

Applications for each academic year are available in January. The priority application deadline for financial aid for the 2021-22 academic year is March 2, 2021.

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 2019-20, the school awarded 170 undergraduate scholarship awards totaling more than $1.1 million. The majority of these scholarships are publicized in the fall, with additional scholarships promoted throughout the academic year as applicable. For more information on all available scholarships, see the school undergraduate scholarships web page.

Grants

Cal Grants A and B are awarded by the California Student Aid Commission to entering and continuing undergraduate students who are U.S. citizens or eligible noncitizens and California residents, based on financial need and academic achievement. Cal Grant A awards are applied toward tuition and fees. Cal Grant B awards help with living expenses, books, supplies, and transportation costs.

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

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

Federal Family Education Loan Program

Student Loan Services and Collections
A227 Murphy Hall
310-825-9864

Federal loans are available to undergraduate or graduate students who are U.S. citizens or eligible noncitizens and who carry at least a half-time academic workload. Information on loan programs is available from Financial Aid and Scholarships.

All loan recipients must complete an exit interview with Loan Services Office before leaving UCLA for any reason. This interview helps students understand their loan agreement and plan for loan repayment. Failure to complete an exit interview results in a hold being placed on all university services and records. In addition, if the campus-based loans become delinquent following separation from UCLA, all university services and records will be withheld. For more information concerning loan repayment, contact Student Loan Services and Collections.

Work-Study Programs

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

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

Community Service is a component of the Federal Work-Study program. Students who secure a community service position are eligible to petition for an increase in work-study funds up to a total of $5,000 while at the same time reducing their Per-
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 supplemental tuition (where applicable). These stipends may be supplemented by a teaching assistantship or graduate student researcher appointment. The awards are generally reserved for new students.

Teaching assistantships are awarded to students on the basis of scholarship and promise as teachers. Appointees serve under the supervision of regular faculty members.

Graduate student researcher (GSR) appointments are awarded to students on the basis of scholastic achievement and promise as creative scholars. Appointees perform research under the supervision of a faculty member in research work. Full-time employment in summer and 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 2020-21 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, A129J Murphy Hall. Financial aid applicants must file the Free Application for Federal Student Aid (FAFSA).

Continuing graduate students should contact Financial Aid and Scholarships in December 2020 for information on 2021-22 application procedures.

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

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2020-21 ANNUAL UCLA UNDERGRADUATE AND GRADUATE STUDENT FEES

Fees subject to revision without notice.

<table>
<thead>
<tr>
<th></th>
<th>Undergraduate Student</th>
<th>Academic Master's Student</th>
<th>Academic Doctoral Student</th>
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<td>Resident Nonresident</td>
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<td>.99</td>
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<td>80.00 80.00</td>
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<td>$16,343.40</td>
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</table>

*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.
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 Beedle Fellowship. Chemical and Biomolecular Engineering Department; supports study in chemical engineering
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 Alynne 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 (C3M) 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 Samuel Fellowship. Electrical and Computer Engineering Department; supports master’s and doctoral students
Henry Samuel 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 (CEED)

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). A total of 103 students participated in SMASH during summer 2019.
MESA College Prep Program. Through CEED, UCLA Samueli partners with middle
and high school principals to implement College Prep 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 College Prep advisers and coordinate the activities and instruction for 1000 students. Advisers work as a team to deliver services that include SAT preparation. College Prep 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 goal of the MESA College Prep Program 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. The UCLA MESA Center currently serves middle and high school students in 17 Los Angeles Unified School District schools, four Inglewood Unified School District schools, and one Centinela Valley Union High School District school.

Undergraduate Programs

CEED currently supports some 344 underrepresented and educationally disadvantaged engineering students. Components of the undergraduate program include the 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 engineering courses. Current CEED students and incoming CEED transfer students take part in lectures and collaborative, problem-solving workshops facilitated by UCLA graduate students.

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.

Scholarships/Financial Aid

UCEA Samueli also participates in the NA-CME 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

UCEA 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)

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 (NSBE)

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, UCLA NSBE offers 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 enjoy-

CEED students participate in a professional development workshop.
ing the college experience. UCLA NSBE was recently named small chapter of the year by the national organization.

**Society of Latino Engineers and Scientists (SOLES)**

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

SOLES also strives to familiarize the UCLA community with the richness and diversity of the Latino culture and the scientific accomplishments of Latinos. SOLES organizes cultural events such as Latinos in Science, Cinco de Mayo, and co-sponsors the Engineers Week, the organization’s growing network. At SOLES, SOLES organizes professional events to emphasize the achievements, research results, 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 student clubs and organizations.

- American Indian Science and Engineering Society (AISES)
- American Institute of Aeronautics and Astronautics (AIAA)
- American Society of Civil Engineers (ASCE)
- American Society of Mechanical Engineers/BattleBots (ASME)
- American Water Works Association (AWWA)
- Association for Computing Machinery (ACM)
- Association for Computing Machinery–Women (ACM-W)
- Biomedical Engineering Society (BMES)
- Blockchain
- Bruin Entrepreneurs
- Bruin Home Solutions
- Bruin Hyperloop
- Bruin Racing Formula SAE Team
- Bruin Racing Supersprint Vehicle Team (SMV)
- Building Engineers and Mentors (BEAM)
- California Geotechnical Engineers Association (CalGeo)
- Chi Epsilon (Civil engineering honor society)
- Design/Build/Fly (DBF)
- Engineering Ambassador Program
- Engineering Graduate Students Association (EGSA)
- Engineering Society, University of California (ESUC) (Umbrella group bridges student body and administration, hosts major events)
- Engineers Without Borders (EWB)
- Eta Kappa Nu (Electrical engineering/computer science and engineering honor society)
- Formula Drone
- IEEE Electron Devices Society (EDS)
- IEEE Electronics Packaging Society (EPS)
- IEEE Women Advancing Technology through Teamwork (WATT)
- Institute of Electrical and Electronic Engineers (IEEE)
- Institute of Transportation Engineers (ITE)
- International Genetically Engineered Machines (iGEM)
- International Society for Pharmaceutical Engineering (ISPE)
- Korean-American Scientists and Engineers Association (BruinKSEA)
- Linux Users Group (LUG)
- Materials Research Society (MRS)
- MentorSEAS
- National Society of Black Engineers (NSBE)
- Phi Sigma Rho (Engineering social sorority)
- Pilipinos in Engineering and Science (PIES)
- Queers in STEM (QSTEM)
- Renewable Energy Association (REA)
- Rocket Project
- Society of Asian Scientists and Engineers (SASE)
- Society of Automotive Engineers (SAE)
- Society of Latino Engineers and Scientists (SOLES)
- Society of Women Engineers (SWE)
- Tau Beta Pi (Engineering honor society)
- Theta Tau (Professional engineering fraternity)
- Triangle (Social fraternity of engineers, architects, and scientists)

**UCLA 3D4E**

**UCLA DevX**

**Upsilon Pi Epsilon (International computing and information 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 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 degrees simultaneously.

Minimum qualifications include the completion of 24 courses (96 quarter units) at UCLA, or the equivalent at a similar institution, a minimum 3.7 grade-point average (GPA) in the major field upper-division courses and a minimum 3.7 cumulative GPA, 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 eligibility criteria and application deadlines, refer to the Departmental Scholar Program web page.

Exceptional Student Admissions Program

UCLA Samueli has an Exceptional Student Admissions Program (ESAP) for its outstanding undergraduates who wish to enter the school graduate program upon completion of the B.S. 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 eligible for consideration of graduate fellowships and teaching assistant positions if available.

For eligibility criteria and graduate application deadlines, refer to the Exceptional Student Admissions Program web page.

Academic Policies

Student Representation

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

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, 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.

Grades

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 report as well as a copy of the associate dean’s recommendation. The student 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 basis 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 injuries to the student by contacting the Office of the Dean of Students by e-mail, or in person at 1104 Murphy Hall. Refer to UCLA Procedure 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, 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 PACAOS-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 reasoning 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 student’s disability. Disability-based harassment is conduct which is sufficiently severe, pervasive, or persistent so as to interfere with or limit an individual's ability to participate in or benefit from the services, activities, or opportunities offered by the University.

UCLA has issued Procedure 230.2: Student Grievances Regarding Violations of Anti-Discrimination Laws or University Policies on Discrimination on Basis of Disability. Students may grieve any action that they believe discriminates against them on the basis of disability by contacting the Office of the Dean of Students by e-mail, or in person at 1104 Murphy Hall. Refer to procedure 230.2 for more information and procedures.
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 Office, 2255 Murphy Hall, 310-206-3417, or the U.S. Department of Education Office for Civil Rights.

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 (PDF, hereafter referred to as the SVSH Policy). The University will respond promptly and effectively to reports of sexual harassment and will take appropriate action to prevent, correct and, if necessary, discipline behavior that violates the SVSH Policy. See the Title IX sexual harassment prevention website.

Definitions

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

Complaint Resolution

An individual who believes that they have been sexually harassed may contact the Title IX director Mohammed Cato, 2255 Murphy Hall, 310-206-3417. 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 Director. 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 Title IX may be directed to the Title IX Office, 2255 Murphy Hall, 310-206-3417, or the U.S. Department of Education Office for Civil Rights.

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) 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.

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.

Complaint Resolution

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

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

In addition to providing support for those who believe they have been victims of harassment, the Office of Student Conduct can help students to consider which of the available options is the most useful for the particular circumstances.

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

Disclosure of Student Records

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

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

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.

Students who do not wish certain items (i.e., name, e-mail address, telephone numbers, major field of study, dates of attendance, number of course units in which enrolled, and degrees and honors received) of this public information released and published may so indicate through MyUCLA. To restrict the release and publication of the additional items in the category of public information, complete the UCLA FERPA Restriction Request form available from the Registrar’s Office, 1113 Murphy Hall.

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

A copy of the federal and state laws, University policies, and the print UCLA Telephone Directory may be inspected in the office of the Information Practices Coordinator, 500 UCLA Wilshire Center. Information concerning students’ hearing rights may be obtained from that office and from the Office of Student Conduct, 1104 Murphy Hall.
### 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. The computer science and computer science and engineering curricula are accredited by the Computing Accreditation Commission of ABET. 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

Applications to UCLA Samueli must satisfy the general UC admission requirements. See the undergraduate admission website for details. Applicants must apply directly to the school by selecting one of the majors within the school or the undeclared option. In the selection process many elements are considered, including grades 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.

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

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

### Admission as a Freshman

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 pre-calculus 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 on the undergraduate admission website.

### 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 2020 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 on the ASSIST website. 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 requirement, 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.
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>ADVANCED PLACEMENT SCORE-TO-CREDIT CONVERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP EXAMINATION</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Art History</td>
</tr>
<tr>
<td>Art, Studio</td>
</tr>
<tr>
<td>Drawing Portfolio</td>
</tr>
<tr>
<td>Two-Dimensional Design Portfolio</td>
</tr>
<tr>
<td>Three-Dimensional Design Portfolio</td>
</tr>
<tr>
<td>Biology</td>
</tr>
<tr>
<td>Chemistry</td>
</tr>
<tr>
<td>4 or 5</td>
</tr>
<tr>
<td>Computer Science</td>
</tr>
<tr>
<td>Computer Science A Test</td>
</tr>
<tr>
<td>Computer Science AB Test</td>
</tr>
<tr>
<td>Computer Science Principles</td>
</tr>
<tr>
<td>Economics</td>
</tr>
<tr>
<td>Macroeconomics</td>
</tr>
<tr>
<td>4 or 5</td>
</tr>
<tr>
<td>Microeconomics</td>
</tr>
<tr>
<td>4 or 5</td>
</tr>
<tr>
<td>English</td>
</tr>
<tr>
<td>8 units maximum for both tests</td>
</tr>
<tr>
<td>Language and Composition</td>
</tr>
<tr>
<td>4 or 5</td>
</tr>
<tr>
<td>Literature and Composition</td>
</tr>
<tr>
<td>4 or 5</td>
</tr>
<tr>
<td>Environmental Science</td>
</tr>
<tr>
<td>Geography, Human</td>
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<tr>
<td>Government and Politics</td>
</tr>
<tr>
<td>Comparative</td>
</tr>
<tr>
<td>United States</td>
</tr>
<tr>
<td>History</td>
</tr>
<tr>
<td>European</td>
</tr>
<tr>
<td>4 or 5</td>
</tr>
<tr>
<td>United States</td>
</tr>
<tr>
<td>World</td>
</tr>
</tbody>
</table>
## Languages and Literatures

<table>
<thead>
<tr>
<th>Subject</th>
<th>Grade(s)</th>
<th>Units Requirement</th>
<th>Application Notes</th>
</tr>
</thead>
<tbody>
<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>
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 on the ASSIST website.

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: 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 science 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 2.0 (C) grade-point average (GPA) in all courses taken at any UC campus, students must achieve at least a 2.0 GPA in all upper-division courses offered in satisfaction of the subject and elective requirements of the curriculum. A 2.0 minimum GPA 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.

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 online or 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. The courses introduce students to the historical development and fundamental intellectual and ethical issues associated with the arts and humanities and may also investigate the complex relations between artistic and humanistic expression and other facets of society and culture.

Foundations of Society and Culture

Two 5-unit courses, one from each subgroup:

- Historical Analysis
- Social Analysis

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 the GE Requirement web page.

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 Samuels GE requirements. The school does not accept partial IGETC.

Department Requirements

UCLA Samuels 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 prepara-
tion 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 Samueli 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. 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 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 Samueli 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 Samueli 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, or online through the petition process web page. 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 schedule an appointment with an academic counselor online.

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.

UCLA Samueli undergraduate students following a Catalog year prior to fall quarter 2012 should schedule an appointment with their academic counselor online 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 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 2020-21 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 3.914 or better) for summa cum laude, next five percent (GPA of 3.857 or better) for magna cum laude, and the next 10 percent (GPA of 3.743 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 3.914 grade-point average for summa cum laude, a 3.857 for magna cum laude, and a 3.743 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.
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 at Program Requirements for UCLA Graduate Degrees.

**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 and Computer 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, a Master of Science student must obtain an overall grade-point average of 3.0 GPA in graduate courses.

**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.

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 more 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

**Materials Science and Engineering Department**

Ceramics and ceramic processing
Electronic and optical materials
Structural materials

**Mechanical and Aerospace Engineering Department**

Applied mathematics (established minor field only)
Applied plasma physics (minor field only)
Design, robotics, and manufacturing (DROM)
Dynamics
Fluid mechanics

Micro-nano engineering
Structural and solid mechanics
Systems and control
Thermal science and engineering

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

**Admission**

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

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

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

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

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

To submit a graduate application, see the school [graduate admissions](#) web page. 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

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

Department e-mail
Department website

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

Professors
Denise R. Aberle, M.D.
Eric Pei-Yu Chou, 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.
Zhen Gu, Ph.D.

Adjunct Faculty

Bioengineering

Adjunct Associate Professors
Sophia N. Barbarie, Ph.D.
Bill J. Tawil, M.B.A., Ph.D.

Adjunct Assistant Professors
Chase Linsley, Ph.D.
George N. Sakkid, 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. Hickey, 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. Sungtaek Ju, Ph.D. (Mechanical and Aerospace Engineering)
H. Phillip Koeffler, M.D., in Residence (Medicine)
Jody E. Kreiman, Ph.D., in Residence (Surgery)
Elliot M. Landaw, M.D., Ph.D. (Biomathematics)
Min Lee, 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)
Istvan Mody, Ph.D. (Neurology, Physiology)
Harold G. Monbcouquette, Ph.D. (Chemical and Biomolecular Engineering)
Samuel S. Murray, M.D., Ph.D., in Residence (Medicine)
Peter M. Nairns, Ph.D. (Ecology and Evolutionary Biology, Integrative Biology and Physiology)
Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)

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Ichiro Nishimura, D.D.S., D.M.Sc., D.M.D. (Dentistry)
Undergraduate Program Educational Objectives

The bioengineering program is accredited by the Engineering Accreditation Commission of ABET.

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.

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 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, C175, 176, 180, Electrical and Computer Engineering 100, Engineering 181EW or 182EW or 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. Six additional major field elective courses (24 units) from Bioengineering C101, C102, C104, C105, C106, C107, C111, C131, C139A, C139B, CM140, CM145, CM147, M153, C155, CM175, C177A, 177B, 180L, M182, 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.
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 total course and unit requirement.

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 once only, subject to the approval of the faculty examination committee. Students who fail the examination twice are not permitted to submit a thesis and are subject to termination.

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 University Oral Qualifying Examination and final oral examination, and complete the courses in Group I and Group II 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.

To remain in good standing in the program, Ph.D. students are expected to take the University Oral Qualifying Examination within six academic quarters and two summer quarters (i.e., two years) following matriculation. 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, the written component of the qualifying examination, prior to the oral qualifying examination.

A doctoral committee consists of a minimum of four qualified UCLA faculty members.

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

Fields of Study

Biomedical Instrumentation

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

Course Requirements

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

Group I: Core Bioengineering Courses. At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, CM278, C283, C285, CM286, an approved topic of 298.

Group II: Elective Courses. At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207,
of advanced engineering skills to the study of anatomy and function.

**Course Requirements**

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Group II: Elective Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Course Requirements**

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Group II: Elective Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Course Requirements**

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Group II: Elective Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Course Requirements**

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Group II: Elective Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Course Requirements**

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

**Group I: Core Bioengineering Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.

**Group II: Elective Courses.** At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, C255, M260, C275, C283, C285, CM286, an approved topic of 298.
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. Grad-uate 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 associat-ed (clinical) data to understand the context of the imaging study, to document observations, and to correlate and reach new conclusions about a disease and the course of a medical problem.

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

Course Requirements

Medical Imaging Informatics students must take the nine Group I: Core Courses on General Concepts, at least three courses from Group II: Subfield Specific Courses, and at least one course from Group III: Ethics Course.

Group I: Core Courses on General Concepts.


Group II: Subfield Specific Courses. M.S. cap-stone students must take any three courses from the four concentrations, and Ph.D. students must take six course, three each from two concentrations.


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


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

Molecular Cellular Tissue Therapeutics

The molecular cellular tissue therapeutics (WCTT) 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 treat-ment, 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

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

Group I: Core Bioengineering Courses.

At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, C229, C239A, C239B, CM245, C255, M260, C275, CM278, C283, C285, CM286, an approved topic of 298.

M230, M248, Physiological Science M135, 166, 200.

**Neuroengineering**

The neuroengineering (NE) field is designed to enable students with a background in biological sciences to develop and execute projects that address problems that have a neuroscience base, including locomotion and pattern generation, central control of movement, and the processing of sensory information. 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 other's language and move comfortably among the intellectual domains of the two fields.

**Course Requirements**

Students must select at least three courses from Group I: Core Bioengineering Courses, and at least six courses from Group II: Elective Courses. A course cannot be used to simultaneously satisfy Group I and Group II course requirements.

**Group I: Core Bioengineering Courses**


**Group II: Elective Courses**

At least three courses selected from Bioengineering C201, C202, C204, C205, C206, C207, M219, M229, C239A, C239B, CM245, CM255, M260, C275, CM278, C283, C285, CM286, an approved topic of 298.

**Faculty Areas of Thesis Guidance**

**Professors**

- Denise R. Aberle, M.D. (U. Kansas, 1979)
  - Medical imaging informatics: imaging-based clinical trials, medical data visualization
- Pei-Yu Chiu, Ph.D. (UC Berkeley, 2005)
  - Optofluidics systems
- Mark S. Cohen, Ph.D. (Rockefeller, 1985)
  - Rapid methods of MRI 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, biomineralization, vascular calcification, mesenchymal stem cells
- Timothy J. Deming, Ph.D. (UC Berkeley, 1993)
  - Polymer synthesis, polymer processing, supramolecular materials, organometallic catalysis, biomimetic materials, polypeptides
- Dino Di Carlo, Ph.D. (UC Berkeley, 2006)
  - Microfluidics, biomedical microdevices, cellular diagnostics, cell analysis and engineering
- Zhen Gu, Ph.D. (UC Berkeley, 2010)
  - Drug delivery, biomaterials, cell therapy, micro- and nano-biotechnology
  - 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 analyses of cellular processes, drug delivery, diagnostics
- Andrea M. Kasko, Ph.D. (U. Akron, 2004)
  - Polymer synthesis, biomaterials, tissue engineering, cell-material interactions
  - Microscale fluid mechanics, transport phenomena in biological systems, physics of contact line phenomena, complex fluids, non-isothermal flows, micro- and nano-heats, guides, microfluidics
- Chang-Jin (CJ) Kim, Ph.D. (UC Berkeley, 1991)
  - Microelectromechanical systems: micro/nano fabrication technologies, structures, actuators, devices, and systems; microfluidics involving surface tension (especially droplets)

**Bioengineering / 33**

Debao 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/mechanotransduction
- Wentai Liu, Ph.D. (U. Michigan, 1983)
  - Neural engineering
  - Remote monitoring, wearable sensors, big data analytics, clinical informatics, health care analytics
- Aydogan Ozcan, Ph.D. (Stanford, 2005)
  - Photonics, nano- 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
  - Mobile health, biosensors, salivary diagnostics, value-based healthcare
- Kalyanam Shivkumar, M.D. (U. Madras, India, 1990), Ph.D. (UCLA, 1999)
  - Mechanisms of cardiac arrhythmias in humans, complex catheter ablation, medical technology for cardiac therapeutic
- Maie St. John, M.D., Ph.D. (Yale, 1999)
  - Novel diagnostic and treatment modalities for head and neck cancer
- Yi Tang, Ph.D. (Caltech, 2002)
  - Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibiotics/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
- Paul S. Weiss, Ph.D. (UC Berkeley, 1986)
  - Atomic-scale surface chemistry and physics, molecular devices, nanolithography, biophysics and neuroscience, nanometer-scale electronics and storage, surface interactions, surface motion, dynamics, and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes
- Gerald C.L. Wong, Ph.D. (UC Berkeley, 1994)
  - Antimicrobials and antibiotic-resistant pathogens, bacterial communities, cystic fibrosis, apoptosis proteins and cancer therapeutics, disinfection and water purification, self-assembly in biology and biotechnology, physical chemistry of solvation, soft condensed matter physics, biophysics
  - Biomaterials, cell-material interactions, materials processing, tissue engineering, prosthetic and regenerative dentistry
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 background for established and emerging subfields of bioengineering, including biosensors, bioinstrumentation, and biosignal processing, biomechanics, biomaterials, tissue engineering, biotechnology, optics and lasers, neuroengineering, 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 intellectual importance, taught by faculty members in their areas of expertise and illuminating many paths of discovery at UCLA. P/NP grading.

Student Research Program. (1 to 2 Tutorial) Supervised research or scholarly work, three hours per week. 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 requirement) to enroll; 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)


C102. Human Physiological Systems for Bioengineering I. (4) Formerly numbered CM102.) Lecture, three hours; laboratory, two hours. Preparation: human molecular biology, biochemistry, and cell biology. Not open to credit for Physiological Sciences major. Overview of basic biological activities and organization of human body in system (organ/tissue) to system basis, with particular emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to biomedical facilities. Concurrently scheduled with course C202. Letter grading. Ms. Seidlits (Sp)

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

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 chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in gene chip, or one protein may be coupled to one 2010. course for enhancing its stability in serum. Wide variety of bioconjugates are used in diagnostics, 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 degradable versus nondegradable linkers. Preparation and discussion of design and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C205. Letter grading. Mr. Deming (F)

C106. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Chemistry 20B, Life Sciences 7A, Mathematics 32B, Physics 1C. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology. Basic physical principles governing electrostatics in dielectric media, building on concepts to ultimately address action potentials and signal propagation in nerve. Topics include Nernst/Planck and Poisson/Boltzmann equations, Nernst potential, Donnan equilibrium, G&K equations, energy in channels, cable equations, action potentials, Hodgkin/Huxley equations, impulse propagation, axon geometry and conduction, dendritic integration. Concurrently scheduled with course C206. Letter grading. Mr. Schmidt (F)

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, including step-growth, chain-growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymerization. Presentation of applications of use of different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C207. Letter grading. Mr. Deming (W)

110. Biotransport and Bioreaction Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 100, Mathematics 32B. Introduction to analysis of fluid flow, heat transfer, mass transfer, binding events, and biochemical reactions in systems of interest to bioengineers, including cells, tissues, organs, human body, extracorporeal devices, tissue engineering systems, and bioartificial organs. Introduction to pharmacokinetic analysis. Letter grading. Mr. Kamei (Sp)


121. Introduction to Microcontrollers. (4) Lecture, one hour; discussion, one hour; laboratory, three hours. Requisites: Civil and Environmental Engineering M20 or Mechanical Engineering M20 or Computer Science 31, and Electrical and Computer Engineering 100, or equivalent. Project-based hands-on introduction to basic and advanced concepts involved in development of proj-
ects using microcontrollers for projects in robotics and microfluidics. Concurrently scheduled with course C238A. Letter grading.

Mr. Gupta (W)

CM145. Molecular Biotechnology for Engineers. (4) (Same as Chemical Engineering CM143S.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enrolled requisite: Engineering 45. Selected topics in molecular biology that form foundation of biotechnology and biomedical industry today. Topics include recombinant DNA technology, molecular research techniques, regulation of gene expression, directed mutagenesis and protein engineering, DNA diagnostics and DNA microarrays, antibody and protein-based diagnostics, genomics and bioinformatics, human genomics, gene therapy, and tissue engineering. Concurrently scheduled with course CM245. Letter grading.

Mr. Liao (F)

C147. Applied Tissue Engineering: Clinical and In-Lab Applications. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: course CM110J, Chemistry 20A, 20B, 20L, Life Sciences 7A. Overview of current topics in tissue engineering, with focus on how to build artificial tissues into regulated clinically viable products. Topics include biomaterials selection, cell source, delivery methods, FDA approval processes, and physical/chemical properties. This course will include skin and artificial skin, bone and cartilage, blood vessels, neurotissue engineering, and liver, kidney, and other organs. Clinical and industrial perspectives of tissue engineering products. Manufacturing constraints, clinical limitations, and regulatory challenges in design and development of tissue-engineering devices. Concurrently scheduled with course CM247.

Letter grading.

Ms. Seiditts (FSp)

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Chemical Engineering M153, Electrical and Computer Engineering M153S, and Mechanical and Aerospace Engineering M183S.) Lecture, four hours; outside study, five hours. Enrolled requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to general manufacturing methods, mechanisms, constraints, and micro/nanofabrication techniques. Focus on concepts, physics, and instruments of various microfabrication and nanofabrication techniques that have been 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.

Ms. Won (W)

C155. Fluid-Particle and Fluid-Structure Interactions in Microflows. (4) Lecture, four hours; laboratory, one hour; outside study, seven hours. Enrolled 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 challenges: field-flow fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics vocabulary and techniques, design and model microfluidic systems to manipulate fluids, cells, and particles, and develop strong intuition for how fluid flows control nanostructured microchannels over range of Reynolds numbers. Concurrently scheduled with course CM255. Letter grading.

Mr. Di Carlo (W)

165EW. Biotechnology Ethics. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Requisites: Chemistry 20A, Life Sciences 7A, and either 164A or 166A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer, Power generation, laboratory simulations and tests. Concurrently scheduled with course CM145. Letter grading.

Mr. Wu (W)

167L. Bioengineering Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enrolled requisite: Chemistry 20L. Laboratory experiments in fluorescence microscopy, biocongjugation, soft lithography, and cell culture culminate in design of engineered surface for cell growth. Introduction to techniques used in laboratories and their underlying physical or chemical properties. Case studies connect laboratory techniques to current biomedical research and reinforce experimental design skills. Letter grading.

Mr. Schmidt (Not offered 2020-21)

C175. Machine Learning and Data-Driven Modeling in Bioengineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: Civil Engineering M20 or Mechanical and Aerospace Engineering M20.4, Computer Science 1, Mathematics 18B, 18C, 20A, 20B, 20L. Overview of the foundational concepts of data analysis and machine-learning methods in bioengineering, focusing on how these techniques can be applied to interpret experimental observations. Topics include probabilities, decision theory, cross-validation, evaluation of variance, reproducible computational workflows, dimensionality reduction, regression, hidden Markov models, and clustering. Students will learn theoretical and practical knowledge of data analysis and machine-learning methods relevant to bioengineering. Application of these methods to experimental data from bioengineering studies. Students become sufficiently familiar with these techniques to design studies incorporating such analyses, execute analysis, and work in teams using similar approaches, and ensure correctness of their results. Concurrently scheduled with course C275. Letter grading.

Mr. Meyer (Sp)

176. Principles of Biocompatibility. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enrolled requisites: course 100, Mathematics 33A, 33B, Physics 1C, Engineering Mechanics C139B. Biomolecular Materials Science II. (4) (Same as Chemical Engineering CM145S.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enrolled requisite: course C239A. Letter grading. Mr. Wong (W)

C139A. 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 basic types of interactions that exist between biomolecules, such as van der Waals interactions, electrostatically modulated electrostatic interactions, hydrophobic interactions, hydration and solvation interactions, polymer-mediated interactions, depletion interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of bioengineering problems, such as those in drug and gene delivery, and other areas. May be taken independently for credit. Concurrently scheduled with course C239A. Letter grading. Mr. Wong (W)

CM139B. Biomolecular Materials Science II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Course C139A is not a requisite to C139B. Overview of chemical and physical foundations of biomolecular materials science that concern materials aspects of molecular biology, cell biology, and bioengineering. Understanding of different basic types of biomolecules, with emphasis on nucleic acids, proteins, and lipids. Study of how biological and biomimetic systems organize into their functional forms. Self-assembly of how these structures impart important biological function. Illustration of these ideas using examples from bioengineering and biomedical engineering. Case study on current topics, including drug delivery technology, cancer therapy, and emerging therapies, and self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C239B. Letter grading. Mr. Wong (W)

CM140. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM140.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanical and Aerospace Engineering M140A (or both 102, and 156A or 156A). Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer, Power generation, laboratory simulations and tests. Concurrently scheduled with course CM145. Letter grading.
eling, give oral presentations, write reports, and participate in bioengineering design competitions or research grading.

CM178. Introduction to Biomaterials. (4) (Same as Materials Science CM180.) Lecture, three hours; discussion, two hours; outside study, seven hours. Required: Chemistry 20A, 20B, and 20L. Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM278. Letter grading. Ms. Kasko (Sp)

M184. Introduction to Computational and Systems Biology. (2) (Same as Computational and Systems Biology M184 and Computer Science M184.) Lecture, four hours; discussion, one hour; outside study, eight hours. Enforced requisites: one course from Civil Engineering M20, Computer Science 31, Mechanical and Aerospace Engineering M20, or Program in Computing 10A; and Life Sciences 30B or Mathematics 38B or 31B. Survey course designed to introduce students to computational and systems modeling and computation in biology and medicine, providing motivation, flavor, and contributions of computational biosciences and aiming for more informed basis for focused studies by students with computational and systems biology interests. Presentations by individual UCLA researchers discussing their active computational and systems biology research. P/NP grading. Ms. DiStefano (Not offered 2020-21)

C185. Introduction to Tissue Engineering. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Required: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering design concepts to regenerate tissues and organs. Guiding principles for proper selection of three basic components for tissue engineering: cells, scaffolds, and molecular signals. Concurrently scheduled with course C285. Letter grading. Ms. Kasko (W)

CM186. Computational Systems Biology: Modeling and Simulation of 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 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 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 mathematical models and simulation for investigation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM286.Letter grading. Ms. DiStefano (W)

CM187. Research Communication in Computational and Systems Biology. (4) (Same as Computational and Systems Biology M187 and Computer Science CM187.) Lecture, four hours; outside study, eight hours. Required: course M182 or CM186 or Computational and Systems Biology M150. Closely directed, interactive, and real research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critiques of oral presentations and written progress reports explain how to proceed with research. Major emphasis on effective research reporting, both oral and written. Concurrently scheduled with course CM287. Letter grading. Ms. DiStefano (W)

C188. Special Courses in Bioengineering. (4) Lecture, four hours: discussion, one hour; outside study, seven hours. Special topics in bioengineering for undergraduate students for research participation credit with topic or instructor change. May be repeated for credit. Letter grading. (F,W,Sp)

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

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

Graduate Courses


C202. Human Physiological Systems for Bioengineering. (4) (Formerly numbered CM202.) Lecture, three hours; laboratory, two hours. Preparation: human muscular, skeletal, and cellular biology. Not open for credit to Physiology Science majors. Broad overview of basic biological activities and organization of human body in system (organ/tissue) system basis, with special emphasis on molecular basis. Modeling/simulation of functional aspect of biological system included. Actual demonstration of biomedical instruments, as well as visits to medical facilities. Concurrently scheduled with course C102. Letter grading. Ms. Seidits (F)

C204. Physical Chemistry of Biomacromolecules. (4) Lecture, three hours; discussion, two hours; outside study, seven hours. Required: Chemistry 20A, 20B, 20L. Physical chemistry of biomacromolecules. Detailed treatment of physical-chemical processes of polymers with emphasis on polymer physics. Investigation of polymer structure and conformation, bulk and solution thermodynamics and phase behavior, polymer networks and viscoelastic behavior. Application of engineering principles to problems involving biomacromolecules such as protein conformation, solution of charged species, and separation and characterization of biomacromolecules. Concurrently scheduled with course C104. Letter grading. Mr. Wong (F)

C205. Engineering of Bioconjugates. (4) Lecture, four hours: discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, 20L. Highly recommended: one organic chemistry course. Bioconjugate chemistry is science of coupling biomolecules for wide range of applications. Oligonucleotides may be coupled to one surface in one polymer 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 aspects of polymerization, functionalization, and conjugation, including choice and design of conjugate linkers depending on type of biomolecule and desired application, such as degradable versus nondegradable linkers, enzymatic degradation and synthesis of synthetic bioconjugates for some sample applications. Concurrently scheduled with course C105. Letter grading. Mr. Deming (F)

C206. Topics in Bioelectricity for Bioengineers. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Required: Chemistry 20B, Life Sciences 7A, Mathematics 33B, Physics 1C. Coverage in depth of physical processes associated with biological membranes and channel proteins, with specific emphasis on electrophysiology.
C207. Polymer Chemistry for Bioengineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course C204 or C205. Fundamental polymer synthesis, including step-growth, chain growth (ionic, radical, metal catalyzed), and ring-opening, with focus on factors that can be used to control chain length, chain length distribution, and chain-end functionality, chain copolymerization, and stereochemistry in polymerizations. Presentation of applications of use of different polymerization techniques. Concepts of step-growth, chain-growth, ring-opening, and coordination polymerization, and effects of synthesis route on polymer properties. Lectures include both theory and practical issues demonstrated through examples. Concurrently scheduled with course C207. Letter grading. Mr. Schmidt (F).


M214A. Digital Speech Processing. (4) (Same as Electrical and Computer Engineering M214A.) Lecture, three hours; laboratory, two hours; outside study, eight hours. Requisite: Computer Engineering 114C. Theory and applications of digital processing of speech signals. Mathematical models of human speech production and perception mechanisms and signal analysis/synthesis. Techniques include linear prediction, filter-bank models, and homomorphic filtering. Applications to speech synthesis, automatic recognition, and hearing aids. Letter grading. Mr. Alwan (W).

M215. Biochemical Reaction Engineering. (4) (Same as Chemical Engineering CM215.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemical Engineering 101C. Use of previously learned concepts of physical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of bioprocessing. Mr. Liao (A).

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 techniques discussed briefly for comparison purposes. Letter grading.

M219. Principles and Applications of Magnetic Resonance Imaging. (4) (Same as Physics and Biology in Medicine M219.) Lecture, three hours; discussion, one hour. Basic principles of magnetic resonance (MR), physics, and image formation. Emphasis on harmonic and analytic expressions, image contrast mechanisms, spin and gradient echoes, Fourier transform imaging methods, structure of pulse sequences, and various scanning parameters. Introduction to advanced techniques in rapid imaging acquisition, 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 information system development and evaluation. Focus on new developments in the field. Definition of this emerging field of study, current research efforts, and future directions in research. Key issues in medical informatics to expose students to different application domains, such as to information systems, data and process modeling, information extraction and representations, information retrieval and visualization, health services research, telemedicine, and health policy. Examination of research efforts and applications. S/U grading.

Mr. Kangarloo (F).

221. Human Anatomy and Physiology for Medical and Imaging Informatics. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to basic human anatomy and physiology, with particular emphasis on understanding and visualization of anatomy and physiology through medical images. Topics relevant to acquisition, representation, and dissemination of anatomical knowledge in computerized clinical applications. Topics include chest, cardiac, neurology, gastrointestinal, musculoskeletal, and lymphatic systems. Introduction to basic imaging physics (magnetic resonance, computed tomography, ultrasound, computed radiography) to provide context for imaging modalities predominantly used to view human anatomy. Students are expected to acquire more formal understanding of human anatomy/physiology. Letter grading. Mr. El-Saden (F).

223A-223B-223C. Programming Laboratories for Medical and Imaging Informatics. (4–4–4) Lecture, two hours; laboratory, two hours; outside study, eight hours. Designed for graduate students. Programming laboratories to support coursework in other medical and imaging informatics introductory curriculum courses. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used in image processing and medical information system infrastructure. Letter grading.

223A. Requisites: Computer Science 31, 32. Program in Computing 20A, 20B. Course 223A is requisite to 223B, which is requisite to 223C. Integrated with topics presented in course M227 to reinforce the concepts presented in that course. Projects focus on understanding medical networking issues and implementation of basic protocols for healthcare environment, with emphasis on use of DICOM, HL7, and other standards. Students are expected to develop a working knowledge of the networking concepts used within informatics. 223B. Requisite: course 223A. Integrated with topics presented in courses 223A, 2217, and M228 to reinforce concepts presented in those courses. Projects focus on medical image manipulation and decision support systems. 223C. Requisite: course 223B. Exposure to programming concepts for medical applications, with focus on basic abstraction techniques used to extract meaningful features from medical text and imaging data and visualize results. Integrated with topics presented in courses 224B and 2226 to reinforce concepts presented in those courses. Projects focus on medical image retrieval, knowledge representation, and visualization. Mr. Meng (F,W,Sp).

224A. Physics and Informatics of Medical Imaging. (4) Lecture, four hours; laboratory, eight hours. Requisites: Mathematics 33A, 33B. Designed for graduate students. Introduction to principles of medical imaging and imaging informatics for nonphysicists. Overview of imaging modalities, X-ray, computed tomography (CT), and magnetic resonance (MR). Topics include signal generation, localization, and quantization. Image representation and analysis techniques, introduction to random fields, spatial characterization (atlasses), denoising, energy representations, and clinical imaging workstation design. Provides basic understanding of issues related to medical image acquisition and analysis. Current research efforts with focus on clinical applications and new types of information made available through these modalities. Letter grading.

Mr. Morioka (W).

224B. Advances in Imaging Informatics. (4) Lecture, four hours; outside study, eight hours. Overview of informatics-based applications of medical imaging with focus on indexing and retrieval in context-based image retrieval, computer-aided detection/diagnosis, and imaging genomics. Introduction to core concepts in information retrieval (IR), relevance feedback, and indexing and retrieval in specific domains. Students will learn how to use their use in medicine (e.g., teaching files, case-based retrieval, etc.). Examination of specific techniques for image feature extraction and processing, feature representation, indexing, and retrieval. Exposure to various knowledge bases and classification (machine/deep learning). Survey of clinical applications of these techniques and ongoing challenges. Letter grading. Mr. Morioka (Sp).

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. Kho (W).

M226. Medical Knowledge Representation. (4) (Same as Information Studies M226.) Seminar, four hours; outside study, eight hours. Designed for graduate students. Issues related to medical knowledge representation and its application in healthcare processes. Topics include data structures used for representing knowledge (conceptual graphs, frame-based models), different data models for representing spatio-temporal information, rule-based implementations, current statistical methods for discovery of knowledge (data mining, statistical classifiers, and hierarchical classification), and basic information retrieval techniques. Review of work in constructing ontologies, with focus on problems in developing and definition. Common medical ontologies, coding schemes, and standardized indices/terminologies (SNOMED, UMLS). Letter grading. Mr. Taira (Sp).

M227. Medical Information Infrastructures and Internet Technologies. (4) (Same as Information Studies M225.) Lecture, four hours; outside study, eight hours. Designed for graduate students. Introduction to networking and information infrastructures in medical environment. Exposure to basic concepts related to networking at several levels: low-level (TCP/IP, services), medium-level (network topologies), and high-level (distributed computing, Web-based services). Commonly used medical communication protocols (HL7, DICOM) and current medical information systems (HIS, RIS, PAC2). Advances in networking, such as wireless health systems, peer-to-peer topologies, grid/cloud computing. Introduction to security and encryption in networked environments. Letter grading.

M228. Medical Decision Making. (4) (Same as Information Studies M228.) 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 making 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, and estimation. Focus on technical advances in medical decision support systems and expert systems, with review of classic and current research. Introduction to statistical decision making and decision-making software packages to familiarize students with current tools. Letter grading. Mr. Kangarloo (W).

M229. Advanced Topics in Magnetic Resonance Imaging. (4) (Same as Physics and Biology in Medicine CM229.) Lecture, four hours. Requisite: course M219. Designed for students interested in pursuing research related to development or translation of new
C239B. Biomolecular Materials Science II. (4) Lecture, four hours; 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, polymer-mediated interactions, depletion interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Case study on current topics, including drug delivery, gene therapy, cancer therapeutics, and emerging pathogens, and relation of self-assembly to disease states. May be taken independently for credit. Concurrently scheduled with course C139B. Letter grading. Mr. Wong (Sp).

CM240. Introduction to Biomechanics. (4) (Same as Mechanical and Aerospace Engineering CM240.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: Mechanics and Aerosp. Engineering 101, 102, and 156A or 156A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics and solid body dynamics. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading. Mr. Gupta (W).

CM239A. Medtech Innovation I: Entrepreneurial Opportunities in Medical Technology. (4) (Same as Management M271A.) Lecture, three hours; outside study, nine hours. Design, develop, and implement bio-medical devices that increase quality of clinical care and result in improved patient outcomes in hospital system. Introduction to intellectual property basics and various medtech business models. Letter grading. Mr. Liu, Mr. Shvikumar, Mr. Wu (Sp).

CM233B. Medtech Innovation II: Prototyping and New Venture Development. (4) (Same as Management M271B.) Lecture, three hours; outside study, nine hours. Requisite: course CM233A. Designed for graduate and professional students in engineering, dentistry, design, law, management, and medicine. Focus on understanding how to identify unmet clinical needs, properly filtering through these needs using various acceptance criteria, and developing conceptual models for potential medtech solutions are explored. Students work in groups to expedite traditional research and development processes to invent and implement new medtech devices that increase quality of clinical care and result in improved patient outcomes in hospital system. Introduction to intellectual property basics and various medtech business models. Letter grading. Mr. Liu, Mr. Shvikumar, 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, polymer-mediated interactions, depletion interactions, molecular recognition, and others. Illustration of these ideas using examples from bioengineering and biomedical engineering. Students should be able to make simple calculations and estimates that allow them to engage broad spectrum of bioengineering and biomedical science as those in drug delivery and tissue engineering. May be taken independently for credit. Concurrently scheduled with course C139A. Letter grading. Mr. Wong (W)

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

C256. 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 insight 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. Applications by fluid mechanics, field theory, field fractionation, inertial focusing, structure-induced separations. Application concepts in internal biological flows and separations for biotechnology. Helps students become sufficiently fluent with fluid mechanics vocabulary and terminology, 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 C155. Letter grading. Mr. Di Carlo (Sp).

C279. Biomaterials-Tissue Interactions. (4)
(Same as Neuroscience 200.) Lecture, two hours; discussion/laboratory, two hours. Prior to first laboratory meeting, students must complete Bloodborne Pathogens training course through UCLA Environment, Health, and Safety. Study of anatomical locations of and relationships between ascending and descending sensory and motor systems from spinal cord to cerebral cortex. Covers cranial nerves and brainstem. Prepares students for interpreting histological images of normal and pathological states. Focus on cardiovascular and vascular systems of brain. Subcortical forebrain areas covered in detail. Integrated anatomy laboratory includes brain dissections and overview of tools for MRI analysis. Letter grading. Mr. DiStefano (Sp)

C275. Materials Science and Data-Driven Modeling in Bioengineering. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Requisites: Civil Engineering M202 or Mechanical and Aerospace Engineering M202. Computer Science M31 Science 32B, 3A. Overview of foundational data analysis and machine-learning methods in bioengineering, focusing on how these techniques can be applied to interpret experimental observations. Topics include model building, cross-validation, dimensionality reduction, regression, hidden Markov models, and clustering. Students will gain practical knowledge of foundational data analysis and machine-learning methods relevant to bioengineering. Application of these methods to experimental data from bioengineering studies. Students will learn to leverage data analysis tools and techniques to design studies incorporating such analyses, execute analysis, and work in teams using similar approaches, and ensure correctness of their results. Concurrently scheduled with course C175. Letter grading. Ms. Kasko (W)

CM278. Introduction to Biomaterials. (4) (Same as Materials Science CM280.) Lecture, three hours; discussion, two hours; outside study, seven hours. Requisites: Chemistry CM20A, 20B, and 20L, or Materials Science 104. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM178. Letter grading. Ms. Kasko (F)

C279. Biomedical Tissue Interactions. (4) Lecture, four hours; outside study, eight hours. Requisite: course C205. Builds upon basic knowledge of biotechnology. Development of bioconjugate methods from primary literature, focusing on specific conjugation: coupling of biologically active molecules to substrates, devices, or one another, especially for applications in living cells and in vivo. Letter grading. Mr. Wu (Not offered 2020-21)

281. Advanced Bioconjugate Design and Methods. (4) Lecture, four hours; outside study, eight hours. Requisite: course C205. Builds upon basic concepts of chemical ligation covered in course C205, and focuses on current state-of-art methods and designs for precise bioconjugate formation, especially in context of living cells. Focus on recently developed bioconjugate methods from primary literature, and their applications in bioengineering. Students gain deep understanding of principles of bioconjugation: coupling of biologically active molecules to substrates, devices, or one another, especially for applications in living cells and in vivo. Letter grading. Mr. Wu (F)


C285. Targeted Drug Delivery and Controlled Drug Release. (4) Lecture, three hours; outside study, eight hours. Requisites: Chemistry CM20A, 20B, and 20L. New therapies require comprehensive understanding of modern biology, physiology, anatomy, and chemistry. Development of novel drug delivery systems can provide specific and temporal delivery of gene products and their controlled release are important in treatment of challenging diseases and relevant to tissue engineering and regenerative medicine. The application of biotechnology and engineering principles to develop biomaterials, scaffolds, and molecular signals. Concurrently scheduled with course C185. Letter grading. Ms. Kasko (Sp)

M284. Functional Neuroimaging: Techniques and Applications. (3) (Same as Neuroscience M205, Physics and Biology in Medicine M285, Psychiatry M285, and Psychology M278.) Lecture, three hours. In-depth examination of activation imaging, including MRI and electrophysiological methods, data acquisition, analysis, and interpretation. Techniques and results obtained thus far in human systems. Focus on understanding technologies, how to design activation imaging paradigms, and how to interpret results. Laboratory sessions introduce computer simulation 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. Requisites: course CM102 or CM202, Chemistry 20A, 20B, 20L. Tissue engineering applies principles of biology and physical sciences with engineering approach to regenerate tissues and organs. Guiding principles for proper selection of three dimensional scaffolds, cells, and molecules. Signal exchanges. Concurrently scheduled with course C175. Letter grading. Mr. Wu (Not offered 2020-21)

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 biosystems modeling and computer simulations for studying biological and biomedical processes and systems at multiple levels of organization. Control system, non-linear, compartmental, predator-prey, pharmacokinetic (PK), pharmacodynamic (PD), cellular. Methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in class and PC laboratory assignments. Concurrently scheduled with course CM186. Letter grading. Mr. DiStefano (F)

CM287. Research Communication in Computational and Systems Biology. (4) (Same as Computer Science CM287.) Lecture, four hours; outside study, eight hours. Requisites: course CM186 or CM286 or Computational and Systems Biology M150. Closely directed, interactive, and real research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, appropriate to student interests and capabilities. Critical evaluation and presentation of literature explores research questions and methods for searching and literature in research specialty of faculty mentors. Research based on cutting-edge developments and challenges in wound healing models, stem cell biology, angiogenesis, signal transduction, gene therapy, cDNA microarray search and literature in research specialty of faculty mentors teaching course. Student presentation of projects in research specialty. May be repeated for credit. S/U grading. 295A. Biomaterial Research. 295B. Biomaterials and Tissue Engineering Research. 295C. Medical Laser Research. 295D. Hybrid Device Research. 295E. Molecular Cell Bioengineering Research. 295F. Biopolymers and Materials Chemistry. 295G. Biomicrofluidics and Biotechnology. 295H. Biomechanics. 295J. Biomechanical Systems Research. 295K. Neural Tissue Engineering and Regenerative Medicine.

M296A. Advanced Modeling Methodology for Diabetic Biomaterial Systems. (4) (Same as Computer Science M270, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisites: course CM286 or M296A or Biomathematics 220. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experimental design in biology and applications in physiology and pharmacology. Letter grading. Mr. DiStefano (W)

M296C. Advanced Topics and Research in Biomedical Systems Modeling and Computing. (4) (Same as Computer Science M296C and Medicine M270E.) Lecture, four hours; outside study, eight hours. Requisite: course M296B. Research techniques and experience on special topics involving mathematical modeling methods for computing in physical, biological and medical sciences. Review and critique of literature. Research problem solving and formulation. Approaches to solutions. Individual MS- and PhD-level project training. Letter grading. Mr. DiStefano (Sp)

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

298. Special Studies in Bioengineering. (4) 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.

299. Seminar: Bioengineering Topics. (2) Seminar, two hours; outside study, four hours. Designed for graduate bioengineering students. Seminar by leading academic and industrial bioengineers from UCLA, other universities, and bioengineering compa-
Tutorial, to be arranged. Limited to graduate search on dissertation. S/U grading.  

495. Teaching Assistant Training Seminar. (2 to 6) Seminar, two hours; outside study, four hours. Limited to graduate bioengineering students. Required of all departmental teaching assistants. May be taken concurrently while holding TA appointment. Seminar on communicating bioengineering and biomedical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids, grading, advising, and rapport with students. S/U grading. 

Mr. Kamei (F) 

596. Directed Individual or Tutorial Studies. (2 to 8) 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. 

597A. 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 Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Reading and preparation for PhD preliminary examinations. S/U grading. 

597C. Preparation for PhD Oral Qualifying 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. Supervised independent research for MS candidates, including thesis prospectus. S/U grading. 

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

Chemical and Biomolecular Engineering 

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

Professors  
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Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)  
Panagiota D. Christofides, Ph.D. (William D. Van Vorst Professor of Chemical Engineering Education)  
Yoram Cohen, Ph.D.  
James F. Davis, Ph.D., Vice Provost  
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Yunfeng Lu, Ph.D.  
Vasilios I. Manousiouthakis, Ph.D.  
Harold G. Monbouquette, Ph.D.  
Stanley J. Osher, Ph.D.  
Philippe Sautet, Ph.D.  
Yi Tang, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering) 

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. Bolber Professor Emeritus of Medical Research)  
Eldon L. Knuth, Ph.D.  
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor Emeritus of Chemical Engineering)  
Selim M. Senkan, Ph.D.  
Vincent L. Vilker, Ph.D.  
A.R. Frank Wazzan, Ph.D., Dean Emeritus  

Associate Professors  
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Yvonne Y. Chen, Ph.D.  

Assistant Professors  
Nasim Annabi, Ph.D.  
Carissa N. Eisler, Ph.D.  
Yuzhang Li, Ph.D.  
Carlos G. Morales-Guido, Ph.D.  
Junyoung G. 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 nanotechnology. On artificial cultivation, nano- and micro-hybrid devices, scaffold engineering, and bioinformatics, S/U grading.

Mr. Wu (F,W,Sp) 

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

496. Teaching Assistant Training Seminar. (2 to 16) Seminar, two hours; outside study, four hours. Limited to graduate bioengineering students. Required of all departmental teaching assistants. May be taken concurrently while holding TA appointment. Seminar on communicating bioengineering and biomedical engineering principles, concepts, and methods; teaching assistant preparation, organization, and presentation of material, including use of visual aids, grading, advising, and rapport with students. S/U grading.

Mr. Kamei (F) 

596. Directed Individual or Tutorial Studies. (2 to 8) 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.

597A. 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 Examinations. (2 to 16) Tutorial, to be arranged. Limited to graduate bioengineering students. Reading and preparation for PhD preliminary examinations. S/U grading.

597C. Preparation for PhD Oral Qualifying 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. Supervised independent research for MS candidates, including thesis prospectus. S/U grading.

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

Chemical and Biomolecular Engineering  

5331 Boelter Hall  
Box 951592  
Los Angeles, CA 90095-1592  
310-825-2046  

Department website  

Department e-mail  

Department website  

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

Professors  
Emily A. Carter, Ph.D. (Executive Vice Chancellor, Provost)  
Jane P. Chang, Ph.D. (William Frederick Seyer Professor of Materials Electrochemistry)  
Panagiota 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.  
Yunfeng Lu, Ph.D.  
Vasilios I. Manousiouthakis, Ph.D.  
Harold G. Monbouquette, Ph.D.  
Stanley J. Osher, Ph.D.  
Philippe Sautet, Ph.D.  
Yi Tang, Ph.D. (Ralph M. Parsons Foundation Professor of Chemical Engineering) 

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. Bolber Professor Emeritus of Medical Research)  
Eldon L. Knuth, Ph.D.  
James C. Liao, Ph.D. (Ralph M. Parsons Foundation Professor Emeritus of Chemical Engineering)  
Selim M. Senkan, Ph.D.  
Vincent L. Vilker, Ph.D.  
A.R. Frank Wazzan, Ph.D., Dean Emeritus  

Associate Professors  
Irene A. Chen, Ph.D.  
Yvonne Y. Chen, Ph.D.  

Assistant Professors  
Nasim Annabi, Ph.D.  
Carissa N. Eisler, Ph.D.  
Yuzhang Li, Ph.D.  
Carlos G. Morales-Guido, Ph.D.  
Junyoung G. 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 nanotechnology. Details of chemical engineering (thermodynamics, transport phenomena, kinetics, reactor engineering and separations), particular emphasis is given to metabolic engineering, protein engineering, synthetic biology, 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.

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 biomolecular 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-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

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, C13A, 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 GE Requirements web page.

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, 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 En-
engineering 108A, 108B); and one biomolecular elective course (4 units) from Bioengineering C105, C106, Chemical Engineering C112, Chemistry and Biochemistry C105, C139, 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 on page 22 or the GE Requirement web page.

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 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 22 or the GE Requirement web page.

Graduate Study

For information on graduate admission, see Graduate Programs on page 26.

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 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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, M152B, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, 111L, 133A, 199, Materials Science and Engineering 110, 120, 130, 131L, 132, 150, 160, 161L, 199, 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, C223, 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 recom-
mendation 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 pre-candidacy 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:

- 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 laboratories are equipped for cutting-edge genetic, biomolecular, and cellular engineering teaching and research. Facilities and equipment include bioreactors, fluorescence microscopy, 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 exchanger and multilayer laser light scattering for production and characterization of biological and semi-synthetic colloids such as micelles and vesicles, and phosphoinager 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 antibiotic activities. Biosensors are being micromachined for detecting neurotransmitters in vivo. New biosensing schemes also are being invented for the detection of endocrine disrupting chemicals in the environment and for the high-throughput screening of drug candidates. Naturally occurring protein nanocapsules are being redesigned at the genetic level for applications in drug delivery and materials synthesis. Finally, the enzymology of extremely thermophilic microbes is being explored for applications in specialty chemical synthesis.

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

The 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 microreactors 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-
Advanced plasma processing tools include atomic layer deposition capabilities; the facility with in-situ vapor phase processing diagnostics including optical emissions spectroscopy, Langmuir probe, and quadruple 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.

Electronic Materials Processing Laboratory

The 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 and 100 nm are of interest both as individual particles and in the form of aggregate structures. The laboratory is equipped with instrumentation for online measurement of aerosols, including optical particle counters, electrical aerosol analyzers, and condensation particle counters. A novel low-pressure impactor designed in the laboratory is used to fractionate particles for morphological analysis in size ranges down to 50 nm (0.05 micron). Also available is a high-volumetric flow rate impactor suitable for collecting particulate matter for chemical analysis. Several types of specially designed aerosol generators are also available, including a laser ablation chamber, tube furnaces, and a specially designed aerosol microreactor.

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

Polymer and Separations Research Laboratory

The 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 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 laboratory 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. UCL-developed software for heat/power integration and reactor network attainable region construction is 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
Panagiota D. Christofides, Ph.D. (U. Minnesota, 1996)
Process modeling, dynamics and control, computational and applied mathematics
Yoram Cohen, Ph.D. (U. Delaware, 1981)
Water treatment and desalination, separation processes, membrane science and technology, surface nanstructuring, pollutant transport nanomaterials and exposure assessment
Intelligent systems in process, control operations and 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
Yunfeng Lu, Ph.D. (U. New Mexico, 1998)
Semiconductor manufacturing and nanotechnology
Vasilios I. Manoussiotakis, Ph.D. (Rensselaer, 1986)
Process systems engineering: modeling, simulation, design, optimization, and control
Harold G. Monboquette, Ph.D. (North Carolina State, 1987)
Biochemical engineering, biosensors, nanotechnology
Computational science, image processing, information science
First principles atom scale simulations; quantum chemistry; applications to heterogeneous catalysis: active sites and reaction mechanisms, nanomaterials for depollution and energy transformation, molecules at surfaces
Yi Tang, Ph.D. (Caltech, 2002)
Biosynthesis of proteins/polypeptides with unnatural amino acids, synthesis of novel antibiotics/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. Ignarro, Ph.D. (U. Minnesota, 1966)
Regulation and modulation of NO production
Eldon L. Knuth, Ph.D. (Caltech, 1953)
Molecular dynamics, thermodynamics, combustion, applications to air pollution control and combustion efficiency
Metabolic engineering, synthetic biology, bioenergy
Selim M. Serkan, Ph.D. (MIT, 1977)
Reaction engineering, combinational catalysis, combustion, laser photoionization, real-time detection, quantum chemistry
A.R. Frank Wazzan, Ph.D. (UC Berkeley, 1963)
Fast reactors, nuclear fuel element modeling, stability and transition of boundary layers, heat transfer
Associate Professors
Irene A. Chen, Ph.D. (Harvard, 2007)
Synthetic living systems, in vitro evolution, molecular biophysics, phage nanotechnology, microbiome
Yvonne Y. Chen, Ph.D. (Caltech, 2011)
Synthetic Biology, gene-circuit engineering, cell-based therapy, T-cell engineering
Assistant Professors
Nasim Arnabi, Ph.D. (U. Sydney, Australia, 2010)
Biomaterials, tissue engineering, 3D bioprinting, microfabrication, nanocomposite hydrogels for drug/gene delivery, surgical sealants/adesives/alkanes, conductive hydrogels for heart tissue regeneration
Carissa N. Eisler, Ph.D. (Caltech, 2016)
Light and energy transport in nanomaterials, nanophotonics, renewable energy

Yuzhang Li, Ph.D. (Stanford, 2018)
Electrochemical energy storage, electrocatalysis, nanomaterials synthesis and characterization, in situ transmission electron microscopy, cryogenic electron microscopy, carbon capture
Carlos G. Magalhães-Guio, 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, catalysis and biomolecular engineering and analysis, design of reactive materials, materials characterization
Samanvaya 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. Manoussiotakis (Not offered 2020-21)

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

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

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 53A. Fundamentals of 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. Man (F)

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. 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 32A. Introduction to analysis and design of industrial chemical processes. Material and energy balances. Introduction to programming in MATLAB. Letter grading. Ms. Eiser (F)

101A. Transport Phenomena I (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Mathematics 33A, 33B. Introduction to analysis of fluid flow, biological, material, and molecular processes. Fundamentals of momentum transport, Newtonian law of viscosity, mass and momentum conservation in laminar flow, Navier-Stokes equations, and engineering applications of these systems. Letter grading. Ms. Eiser (W)


101C. Mass Transfer. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101A. Introduction to mass transfer in chemical, biological, material, and molecular processes. Fundamentals of species transport, Fick law of diffusion, diffusion in constrained systems, forced requisite: course 101B. Introduction to analysis of diffusion, mass transport, and free convection, radiation, and engineering analysis of mass transfer in process systems. Letter grading. Ms. Eiser (W)

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

102B. Thermodynamics II. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 102A. Application of fundamentals of chemical and biomolecular engineering. Phases in equilibrium and non-equilibrium. Chemical reaction equilibria. Statistical ensembles and partition functions. Statistical thermodynamics of ideal gas. Interfacial interactions and liquid state. Thermodynamics of polymers and biological macromolecules. Letter grading. Mr. Sautet (Sp)

103. Separation Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101A. 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. Mr. Monbouquette (W)

104A. Chemical and Biomolecular Engineering Laboratory I. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requisites: 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 and performance of original experimental study involving transport, separation, or another aspect of chemical and biomolecular engineering. Basic statistics: mean, standard deviation, confidence limits, comparison of two means and of multiple means, single and multiple variable linear regression, and brief introduction to factorial design of experiments. English and power presentation. Technical writing of sections of technical reports and their contents; writing clearly, concisely, and consistently; importance of word choices and punctuation in multi-cultural-English environment. Follow-up of requiring W letter grading. Mr. Li, Mr. Lu, Mc Simonetti (W,Sp)

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

104C. Semiconductor Processing. (3) Lecture, four hours; outside study, five hours. Enforced requisites: 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, and metalization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Ms. Chang (Sp)

104CL. Semiconductor Processing Laboratory. (3) Laboratory, four hours; outside study, five hours. Enforced requisites: course 101C. Enforced corequisite: course 104C. Series of experiments that emphasize basic engineering principles of semiconductor unit operations, including fabrication and characterization of semiconductor devices. Investigation of processing steps used to make CMOS devices, including wafer cleaning, oxidation, diffusion, lithography, chemical vapor deposition, plasma etching, and metalization. Hands-on device testing includes transistors, diodes, and capacitors. Letter grading. Ms. Chang (Sp)

104D. Molecular Biotechnology Laboratory: From Gene to Product. (6) Lecture, two hours; laboratory, eight hours; outside study, eight hours. Enforced requisites: courses 101C, 125S. Integration of molecular and engineering science principles to biotechnology. Cloning of protein-coding gene into plasmid, transformation of construct into E. coli, production of gene product in bioreactor, downstream processing of bioreactor broth to purify recombinant protein, and characterization of purified protein by spectroscopic and analytical methods. Ms. Chen, Mr. Park (W,Sp)

106. Chemical Reaction Engineering. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101C, 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 requisites: courses 101C, 103 (or 125), 106 (or 115), Principles of dynamics modeling and state-space representation of chemical engineering processes. Chemical process control elements. Design and applications of chemical process computer control. Letter grading. Mr. Christofides (W)

108A. Process Economics and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or 125), 104A, 106 (or 115). Integration of chemical engineering modeling and state-space representation of chemical phenomena, thermodynamics, separation operations, and reaction engineering and simple economic principles for purposes of designing chemical processes and evaluating alternatives. Letter grading. Mr. Christofides (W)

108B. Chemical Process Computer-Aided Design and Analysis. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or 125), 106 (or 115), 108A, Civil and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Introduction to application of some mathematical and computing methods to chemical engineering design problems; use of simulation programs as automated method of performing steady state material and energy balance calculations. Letter grading. Mr. Morales Guio (Sp)

109. Numerical and Mathematical Methods in Chemical and Biological Engineering. (4) Lecture, four hours; discussion, seven hours. Enforced requisites: course 102B. Principles and engineering applications of statistical and phenomenological thermodynamics. Fundamentals of partition function in terms of simple molecular models and spectroscopic data; nonideal gases; phase transitions and adsorption; nonequilibrium thermodynamics and coupled transport processes. Letter grading. Mr. Christofides (F)

110. Intermediate Engineering Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: course 102B. Principles and engineering applications of statistical and phenomenological thermodynamics. Determination of partition function in terms of simple molecular models and spectroscopic data; nonideal gases; phase transitions and adsorption; nonequilibrium thermodynamics and coupled transport processes. Letter grading. (Not offered 2020-21)

C111. Cryogenics and Low-Temperature Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 102A, 102B (or Materials Science 130). Introduction to cryogenics and low-temperature science pertaining to industrial low-temperature processes. Basic approach to analysis of cryofields and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrency scheduled with course C211. Letter grading. (Not offered 2020-21)

C112. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization, and relationship of air quality to emission sources. Ms. Chang (Sp)

113. Air Pollution Engineering. (4) Lecture, four hours; preparation, two hours; outside study, six hours. Enforced requisites: courses 101C, 102B. Introduction to the physical, chemical, and biological processes control of atmospheric pollutants, air pollution standards, air pollution sources and control technology, and relationship of air quality to emission sources. Letter grading. (Not offered 2020-21)

CM114. Electrochemical Processes. (Formerly numbered C114.) (Same as Materials Science CM114.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 101C, 125S. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization, and relationship of air quality to emission sources. Ms. Chang (Sp)

CM115. Electrochemical Processes. (4) Formerly numbered C114.) (Same as Materials Science CM115.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 106 (or C115), 108A, Civil and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization, and relationship of air quality to emission sources. Ms. Chang (Sp)

CM163. Electrochemical Processes. (4) Formerly numbered C114.) (Same as Materials Science CM114.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 106 (or C115), 108A, Civil and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization, and relationship of air quality to emission sources. Ms. Chang (Sp)

CM164. Electrochemical Processes. (4) Formerly numbered C114.) (Same as Materials Science CM114.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 103 (or C125), 106 (or C115), 108A, Civil and Environmental Engineering M20 (or Mechanical and Aerospace Engineering M20). Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization, and relationship of air quality to emission sources. Ms. Chang (Sp)
teries, solid-state electrochemistry. May be concur-rently scheduled with course CM214. Letter grading. Mr. Morales Guio

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 biochemical thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course CM214. 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 importance, particularly catalytic surfaces and thin films for solid-state electronic devices. Topics include classification of crystals and surfaces, analysis of structure and composition of crystals and their surfaces and interfaces. Examination of engineer-ing applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C216. Letter grading.

Mr. Lu

C118. Multimedia Environmental Assessment. (4) Lecture, four hours; discussion, one hour; preparation, two hours; outside study, five hours. Recommended requisite: courses 101C, 102B. Pollutant sources and their impacts; source releases, waste minimization, transport and fate of chemical pollutants in environment, intermedia transfers of pollutants, multimedia modeling of chemical partitioning in environment, and economic factors used to design processes for complex systems. Concurrently scheduled with course C227. Letter grading.

Mr. Cohen


Letter grading.

Mr. Manoussiouthakis (Not offered 2020-21)

C212. 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 engineering; emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation properties. Use of nanotechnology in design of selective membranes and models of membrane transport (flux and selectivity). Examples provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedical devices. Concurrently scheduled with course C221.

Letter grading.

Mr. Cohen (Sp)

C214. 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 microenviron-ment and design of extracellular matrix analogs using biological and engineering principles. Biomaterials for growth factor, and DNA and siRNA delivery as therapeutics and to facilitate tissue regeneration. Use of stem cells in tissue engineering. Concurrently scheduled with course C224. Letter grading.

Ms. Annabi (W)

C125. Bioseparations and Bioprocess Engineer-ing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced corequisite: course 101C. Separation strategies, unit operations, and economic factors used to design processes for isolating and purifying materials like whole cells, en-zymes, food additives, or pharmaceuticals that are products of biological reactors. Concurrently sched-uled with course CM225. Letter grading.

Ms. Annabi (Sp)

CM127. Synthetic Biology for Biofuels. (4) (Same as Chemistry CM127.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: Chemical Engineering CM125. Engineering applications of complex phenotype is common goal of metabolic en-gineering and synthetic biology. Production of advanced biofuels involves designing and constructing novel metabolic networks in cells. Such efforts require profound understanding of biochemistry, pro-tein structure, and biological regulations and are aided by tools in bioinformatics, systems biology, and molecular biology. Use of metabolic bio-chemistry, protein structure and function, and bioin-formatics. Use of systems modeling for metabolic networks to design microorganisms for energy appli-cations. Use of selected topics in (not offered 2020-21)

Letter grading.

C128. Hydrogen. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: Chemistry 20A. Electronic, physical, and chemical properties of hydrogen. Various methods of production, including production through methane steam reforming, electrolysis, and thermochemical cycles. Description in depth of several uses of hy-drogen, including combustion, cryogenic applications, and hy-drogen fuel cells. Concurrently scheduled with course C228. Letter grading.

Mr. Manoussiouthakis (Sp)

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

(Not offered 2020-21)


(Not offered 2020-21)

CM145. Molecular Biotechnology for Engineers. (4) (Same as Bioengineering CM145.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 101C. Applications of DNA technology, molecular research tools, manipulation of gene expression, directed mutagen-esis 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 engi-neering. Concurrently scheduled with course CM242. Letter grading.

Mr. Park (F)

M135. Introduction to Microscale and Nanoscale Manufacturing. (4) (Same as Bioengineering M135, Electrical and Computer Engineering M152B, and Me-chanical and Aeronautical Engineering M138BL.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Chemistry 20A, Physics 1A, 1B, 1C, 4AL, 4BL. Introduction to general manufacturing methods, mechanical systems, and microfabrication and nanofabrication. Focus on concepts, physics, and instruments of various micro-fabrication and nanofabrication techniques that have been broadly applied in industry and academia, in-cluding various photolithography technologies, phys-ical and chemical deposition methods, and physical and chemical etching methods. Hands-on experi-ence for fabricating microstructures and nanostru-cures in modern cleanroom environment. Letter grading.

C188. Special Courses in Chemical Engineering. (4) Seminar, four hours; outside study, eight hours. Special topics in chemical engineering for undergraduate students taught on experimental or temporary basis. Topics include various projects supervised by resident and visiting faculty members. May be repeated once for credit with topic or instructor change. Letter grading.

194. Research Group Seminars: Chemical Engi-neering. (4) Seminar, four hours; outside study, eight hours. Designed for undergraduate students who are part of research group. Discussion of research methods and current literature in field. May be re-peated for credit. Letter grading may be re-peated for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading.

(F,Sp)

Graduate Courses

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

Mr. Sautet (F)

201. Methods of Molecular Simulation. (4) Lecture, four hours; outside study, eight hours. Requisite: course 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 2020-21)


Mr. Simonetti (W)

C211. Cryogenics and Low-Temperature Process-ess. (4) Lecture, four hours; outside study, seven hours. Fundamentals of cryogenics and cryogenic engineering science pertaining to industrial low-temperature processes. Basic approaches to analysis of cryofluids and envelopes needed for operation of cryogenic systems; low-temperature behavior of matter, optimization of cryosystems and other special conditions. Concurrently scheduled with course C111. Letter grading.

(Not offered 2020-21)

C212. Polymer Processes. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A, Chemistry 30A. Formation of polymers, criteria for selecting reaction scheme, polymerization techniques, polymer characterization. Mechanical properties. Rheology of macromolecules, polymer process engineering, Diffusion in polymer systems. Polymer reaction engineering into industrial 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 C214.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 102B, Mechanical and Aerospace Engineering 105A (or Ma-terials Science 130). Fundamentals of electrochem-istry and engineering applications to industrial elec trochemical processes. Primary emphasis on funda-mental approach to analyze electrochemical
C216. 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 classification of crystals and surfaces, analysis, pulsed laser deposition, controlled reactions at their surfaces and interfaces. Examination of engineering applications, including catalytic surfaces, interfaces in microelectronics, and solid-state laser. May be concurrently scheduled with course C115. Letter grading. Ms. Annabi (Fall).

CM215. Biochemical Reaction Engineering. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 114C. Use of previously learned concepts of biophysical chemistry, thermodynamics, transport phenomena, and reaction kinetics to develop tools needed for technical design and economic analysis of biological reactors. May be concurrently scheduled with course C115. Letter grading. Mr. Morales Quilo (Spring).

C222A. Stochastic Modeling and Simulation of Chemical Processes. (4) Lecture, four hours; outside study, eight hours. Introduction, definition, rationale of stochastic processes, distributions, correlation, and independence. Mean square calculi, Wiener process, white noise, Poisson process. Generalized functions. Linear systems with stochastic inputs, ergodicity. Applications to chemical process modeling and simulation, Markov chains and processes, its integrals, stochastic difference, and differential equations. S/U or letter grading. Mr. Manousiouthakis (Not offered 2020-21).
CM245. Molecular Biotechnology for Engineers. (4) (Same as CM245L) Lecture, four hours; discussion, one hour; outside study, seven hours. Selected topics in molecular biology that form foundation of biotechnology and biomedical technology today, including recombinant DNA technology, molecular research tools, manipulation of gene expression, directed mutagenesis and protein engineering, DNA-based diagnostics and DNA microarrays, anti-biodyne-based diagnostics, genomics and bioinformatics, isolation of human genes, gene therapy, and tissue engineering. Concurrently scheduled with course CM145. Letter grading.


Mr. Park (F)

260. Non-Newtonian Fluid Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisites: course 108B. Application of optimization methods in chemical process design; computer aids in process engineering; process modeling; systematic flowsheet invention; process synthesis; optimal design and operation of large-scale chemical processing systems. Letter grading.

Mr. Manousiouthakis (Not offered 2020-21)


Mr. Manousiouthakis (Not offered 2020-21)


Mr. Cohen (Not offered 2020-21)

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

Ms. Chang

270R. Advanced Research in Semiconductor Manufacturing. (8) 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.

280A. Linear Dynamic Systems. (4) (Same as Electrical and Computer Engineering 280A and Mechanical and Aerospace Engineering 270A.) Lecture, four hours; outside study, eight hours. Requisites: 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 algebra concepts such as eigenvalues and eigenvectors, Cayley-Hamilton theorem, Jordan form; solution of state equations; stability, controllability, observability, realizability, and minimality. Stabilization design via state feedback and state-observer constructions; connections with transfer function techniques. Letter grading.

280C. Optimal Control. (4) (Same as Electrical and Computer Engineering 280C and Mechanical and Aerospace Engineering 270C.) Lecture, four hours; outside study, eight hours. Requisites: course 280A or Electrical and Computer Engineering 270A. 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.

283C. Analysis and Control of Infinite Dimensional Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 280A, 282A. Design 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. (Not offered 2020-21)


290. Special Topics. (2 to 16) Seminar, to be arranged. Limited to graduate chemical engineering students in MS semiconductor manufacturing option. Reading and preparation for oral qualifying examination, including preliminary research on dissertation. S/U grading.

298. Research for and Preparation of M.S. Thesis. (2 to 16) Seminar, to be arranged. Limited to graduate chemical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

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

and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading. (F,W,Sp)

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

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

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

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

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

598. Research for and Preparation of M.S. Thesis. (2 to 12) Tutorial, to be arranged. Limited to graduate chemical engineering students. Usually taken after students have been advanced to candidacy. S/U grading.

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

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Jian Zhang, Ph.D.

Professors Emeriti
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Michael E. Fourney, Ph.D., P.E.
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Associate Professors
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Henry V. Burton, Ph.D., S.E. (Englekirk Presidential Endowed Professor of Structural Engineering)
David Jassby, Ph.D.
Jiaqi Ma, Ph.D.

Assistant Professors
Timu W. Gallien, Ph.D.
Sanjay Mohanty, Ph.D.
Xiaoyu (Rayne) Zheng, 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 Sabel, Ph.D., S.E.

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

Scope and Objectives
The Department of Civil and Environmental Engineering programs at UCLA include civil engineering materials, earthquake engineering, environmental engineering, geotechnical engineering, hydrology and water resources engineering, structural engineering, and structural mechanics.

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

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

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

Undergraduate Program Educational Objectives
The civil engineering program is accredited by the Engineering Accreditation Commission of ABET.

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, N20 (or Computer Science 31); Mathematics 31A, 31B, 32A, 32B, 33A, 33B (or Mechanical and Aerospace Engineering 82); Physics 1A, 1B, 1C, 4AL; one natural science course selected from Civil and Envi-
Environmental Engineering Minor

The Environmental Engineering minor is designed for students who wish to augment their major program of study with an exposure to engineering methods applied to key environmental problems facing modern society in developed and developing countries. The minor also offers students a brief experience and understanding of the roles that environmental engineering methods play in solving environmental problems.

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.


A minimum of 20 upper-division 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 26.

The following introductory information is based on 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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 undergraduate counseling.
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 preparatory 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, C215B, C215C, C223A, C223B, C226A, 275, 276B, 277, Civil and Environmental Engineering 110, M135C, 153, 154, 155, 157B, 157C, 157L, M165, 226, 250A through 250D, 251C, 251D, 252, 253, 254A, 255A, 255B, 258A, 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.

Geotechnical Engineering

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

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

Major Field Elective Courses. Civil and Environmental Engineering 224, 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, 246, and at least three courses from Civil and Environmental Engineering 235B, C239, 241, 243A, 244, 245, 247.

Elective Courses. Undergraduate—no more than two courses from Civil and Environmental Engineering M135C, 143, and either 141 or 142 (whichever was not used as a requirement for graduate courses); geotechnical 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, C239, 241, 243A, 243B, 244, 245, 247, Mechanical and Aerospace Engineering 269B.

Civil and Environmental Engineering 125 may not be applied toward elective courses.

Structural Mechanics

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

Required Graduate Courses. Civil and Environmental Engineering 232, 235A, 235B, M237A, 244.


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 mechanics (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).


Comprehensive Examination Capstone Plan
In addition to the course requirements, a comprehensive examination (capstone) 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 examination. 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 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 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 Office of Academic and Student Affairs.

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 an 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 nano-to-macro scales. Special efforts are devoted toward developing low-clinker cement and concrete, 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 as well as treatment technologies 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 Laboratory
This field laboratory teaches basic and advanced geomatics techniques including light detection and range (LiDAR) imaging, georeferencing 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 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 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 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 laboratory is used for conducting free and forced vibration and earthquake response experiments on small model structures such as a three-story building, a por-
tal frame, and a water intake/outlet tower for a reservoir. Two electromagnetic exciters, each with a 30-pound dynamic force rating, are available for generating steady state forced vibrations. A number of accelerometers, LVDTs (displacement transducers), and potentiometers are available for measuring the motions of the structure. A laboratory view-based computer-controlled dynamic data acquisition system, an oscilloscope, and a spectrum analyzer are used to visualize and record the motion of the model structures.

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

Reinforced Concrete Laboratory
The 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 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. Students enrolled in the Advanced Soil Mechanics Laboratory course 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 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 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 laboratories are used for conducting water and waste-water analysis, including instrumental techniques such as microcopy, PCR, qPCR, 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 and remediation of pollutants in soil; membrane fouling; toxicity assessment and removal of contaminants from drinking, ground, storm, and waste water; and computer simulation of a variety of environmental processes.

Experimental Mechanics Laboratory
The laboratory supports two major laboratories: 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.

Labratory for the Chemistry of Construction Materials (LC)
LABORATORY FOR THE CHEMISTRY OF CONSTRUCTION MATERIALS research efforts are directed toward 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 so-called 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)
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 (LC), 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 facility allows investigation of the behavior of large-scale structural components and systems subjected to gravity and earthquake loadings. The facility consists of a high-bay area with a 20 ft. x 50 ft. strong floor with anchor points at 3 ft. on center. Actuators with servohydraulic controllers are used to apply monotonic or cyclic loads. The area is serviced by two cranes. The facilities are capable of testing large-scale structural components under a variety of axial and lateral loadings.

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

The 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

Yousef 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

Mokennon Gebremichael, Ph.D. (U. Iowa, 2004)
Remote sensing of hydrology, watershed hydrologic modeling, hydrometeorology, stochastic processes and scaling

Eric M.V. Hoek, Ph.D. (Yale, 2001)
Physical and chemical environmental processes, colloidal and interfacial phenomena, environmental membrane separations, bioadsorption and biofouling

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

Damage mechanics, mechanics of composite materials, computational plasticity, micromechanics, concrete modeling and durability, computational mechanics

Dennis P. Lettenmaier, Ph.D., NAE (U. Washington, 1979)
Hydrologic modeling and prediction, hydroclimate-interactions, hydrologic change

Shaily 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

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

Gaurav N. Sant, Ph.D. (Purdue, 2009)
Cementitious materials and porous media with focus on chemistry-structure-property relationships and interfacial thermodynamics of materials

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

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

Ertugrul Tacioglu, Ph.D. (U. Illinois Urbana-Champaign, 1998)
Computational structural and solid mechanics, constitutive modeling of materials, structural health monitoring, performance-based earthquake engineering, soil-structure interaction

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

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

Professors Emeriti

Stanley B. Dong, Ph.D., P.E. (UC Berkeley, 1967)
Structural mechanics, structural dynamics, finite element methods, numerical methods and mechanics of composite materials

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

Michael E. Fourny, 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. Perrine, Ph.D. (Stanford, 1953)
Resource and environmental problems—chemical, petroleum, or hydrological; physics of flow through porous media; transport phenomena; kinetics

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

Lawrence G. Selna, Ph.D., S.E. (UC Berkeley, 1967)
Reinforced concrete, earthqquake engineering

Keith D. Stolzenbach, 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

Mathieu Bauchy, Ph.D. (U. Pierre et Marie Curie, France, 2012)
Development of high-performance and sustainable glasses and cementitious materials for infrastructure and handled devices applications; multi-scale simulations of materials

Henry V. Burton, Ph.D., S.E. (Stanford, 2014)
Performance-based earthquake engineering, seismic design, evaluation and retrofit, enhanced seismic performance systems, building community resilience

David Jassby, Ph.D. (Duke, 2011)
Water treatment and desalination, membrane separation processes, membrane material fabrication, electrochemistry, environmental applications of nanotechnology

Jiag Ma, Ph.D. (U. Virginia, 2014)
Transportation engineering, connected and automated vehicles, mobility systems, transportation systems resilience, intelligent transportation systems

Assistant Professors

Timu W. Gallien, 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

Adjunct Professors

Geometrics and terrestrial lidar-topographic modeling, geotechnical earthquake engineering, engineering geology, applied geophysics

Michael J. McGuire, Ph.D., P.E., NAE (Drexel, 1977)
Control of trace organics in water treatment including activated carbon

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


58SL. Climate Change, Water Quality, and Ecosystem Functioning. (6) Lecture, four hours. Service learning, two hours; outside study, nine hours. Science related to climate change, water quality, and
Upper-Division Courses

102. Dynamics of Particles and Bodies. (2) Lecture, two hours; discussion, two hours; outside study, two hours. Requisites: course 91, Physics 1B. Introduction to fundamentals of dynamics of single particles, systems, and rigid bodies. Topics include kinematics and kinetics of particles, work and energy, impulse and momentum, multiparticle 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. Prerequisites: courses 31A, 31B, 32B, Physics 1A, 1B, 1C. Corequisites: course 101, Chemistry 20A, 20B. Mathematics 32A, 33A, Recommended: course M20. Introduction to fundamental concepts and applications of probability and statistics in civil engineering, with focus on how these concepts are used in experimental design and sampling, data analysis, risk and reliability analysis, and project design under uncertainty. Topics include basic probability concepts, random variables and analytical probability distributions, functions of random variables, estimating parameters from observational data, regression, hypothesis testing, and Bayesian concepts. Letter grading. Ms. Stewart (Sp)

108L. Experimental Structural Mechanics. (4) Formerly numbered 130L.) Lecture, two hours; laboratory, six hours; outside study, four hours. Prerequisite or corequisite: course 108. Laboratory experiments in various structural mechanics testing of metals, (steel, aluminum, brass), high-strength plastics, and concrete (cylinders, beams). Direct tension, direct compression, bending, shear, and torsion test results are analyzed. Stress and stresses caused by tension, compression, bending, shear, and torsion of slender members. Structural applications to trusses, beams, shafts, and columns. Introduction to virtual work principle. Letter grading. Mr. Bauchy, Ms. Zhang (W,Sp)

108L. Experimental Structural Mechanics. (4) Formerly numbered 130L.) Lecture, two hours; laboratory, six hours; outside study, four hours. Prerequisite or corequisite: course 108. Laboratory experiments in various structural mechanics testing of metals, (steel, aluminum, brass), high-strength plastics, and concrete (cylinders, beams). Direct tension, direct compression, bending, shear, and torsion test results are analyzed. Stress and stresses caused by tension, compression, bending, shear, and torsion of slender members. Structural applications to trusses, beams, shafts, and columns. Introduction to virtual work principle. Letter grading. Mr. Bauchy, Ms. Zhang (W,Sp)

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

120L. Engineering Geomatics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisites: course M20 (or Computer Science 31). Introduction to structural analysis; classification of structural elements; analysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of indeterminate structures using force method; calculation of displacement methods and energy concepts. Letter grading. Mr. Ju (F)

125A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: courses M20 or (Computer Science 31). Introduction to structural analysis; classification of structural elements; analysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of indeterminate structures using force method; introduction to displacement method and energy concepts. Letter grading. Mr. Ju (F)

125B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: course 135A. Analysis of truss and frame structures; stresses in beams with general cross-sections; shear center, deflection of beams, torsion of beams, warping, column instability and failure. Letter grading. Mr. Taciroglu (Sp)

129L. Engineering Geomatics. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses M20 or (Commuter Science 31). Introduction to structural analysis; classification of structural elements; analysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of indeterminate structures using force method; calculation of displacement methods and energy concepts. Letter grading. Mr. Ju (F)

135A. Elementary Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: courses M20 or (Computer Science 31). Introduction to structural analysis; classification of structural elements; analysis of statically determinate trusses, beams, and frames; deflections in elementary structures; virtual work; analysis of indeterminate structures using force method; introduction to displacement method and energy concepts. Letter grading. Mr. Taciroglu (Sp)

135B. Intermediate Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Prerequisite: course 135A. Analysis of truss and frame structures; stresses in beams with general cross-sections; shear center, deflection of beams, torsion of beams, warping, column instability and failure. Letter grading. Mr. Ju (F)

139L. Engineering Geomatics. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Requisites: courses M20, 135A. Analysis of truss and frame structures; stresses in beams with general cross-sections; shear center, deflection of beams, torsion of beams, warping, column instability and failure. Letter grading. Mr. Ju (F)

M135C. Introduction to Finite Element Methods. (4) Same as Mechanical and Aerospace Engineering M168B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 130 or Mechanical and Aerospace Engineering 156A or 166A. Introduction to basic concepts of finite element methods (FEM) and applications to structural and solid mechanics and heat transfer. Direct matrix structural analysis; weighted residual, least squares, and Ritz approximation methods; shape functions; convergence properties; isoparametric formulation of multidimensional heat flow and elasticity; numerical integration. Practical use of FEM software: geometric and analytical modeling; pre-processing and post-processing techniques; term projects with computers. Letter grading. Mr. Taciroglu (Sp)

135L. Structural Design and Testing Laboratory. (4) Lecture two hours; laboratory, four hours; outside study, five hours. Requisites: courses M20, 135A. Limited enrollment. Computer-aided optimum design, construction, instrumentation, and test of small-scale model structure. Use of computer-based data

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137L. Structural Dynamics Laboratory. (4) Lecture, two hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Statics of structural systems. Emphasis on practical design components, in- cluding design applied to water resources engineering. Letter grading. Ms. Gallien (W)

157C. Design of Wastewater Treatment Plants. (4) Lecture, four hours; outside study, eight hours. Req uisites: courses 155, 190. Process design of waste water treatment plants, including primary and secondary treatment, detailed design review of existing plants, process control, and economics. Letter grading. Mr. Stenstrom (W)

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

C159. Green Infrastructure. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 150, 153. Overview of fundamental science, engineering, and ecological principles tied to de signing green infrastructure for stormwater management. Students design green infrastructure based on current practices, perform engineering calculations to calculate performance, and develop critical thinking skills needed for design innovative or futur ic environments, air-water exchange, acid-base equilib ria, biogeochemical cycling, contamination, biodegradation, and bioaccumulation. Practical quantitative problems solved considering both reac tion and transport of chemicals in environment. Letter grading. Mr. Srinivasan (F)

155. Unit Operations and Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 153. Biological, chemical, and physical methods used to modify water quality. Chemicals and 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, two hours; outside study, four hours. Requisites: course 153 (may be taken concurrently). Chemistry 20A, 20B. Basic laboratory techniques in analytical chemistry related to water and wastewater analysis. Selected experiments include gravimetric analysis, titrimetry spectrophotometry, redox systems, pH and electrical conductivity. Concepts to be applied to analysis of real water samples in course 156B. Letter grading. Mr. Stenstrom (Sp)

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acquisition and interpretation systems for compar ison of effects, computationally precise, quantitative behavior. Letter grading. Mr. Burton (Sp)

137. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135B. Basic structural dynamics concepts for civil 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 multi-degree freedom systems. Time-domain behavior, bending, and torsional vibration of beams. Concurrently scheduled with course C239. Letter grading. Mr. Taciroglu (F)

144. Structural Systems Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 141 or 142, and 190. Design course for civil engineering students, with focus on design and performance of complete building structural systems: transmitted gravity loads (IBC), and ASCE 7 dead, live, wind, and earthquake loads. Design of reinforced concrete and structural steel buildings. Computer modeling, analysis, and performance assessment of buildings. Letter grading. Mr. Wallace (Sp)

147. Design and Construction of Tall Buildings. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 135B, 141, 190. Role of structural systems and other design professions in design process. Development of architectural 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. Letter grading. Mr. Sabol (W)

148. Wood and Timber Design. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses 108, 135A. Properties of wood and wood products, analysis and design of wood and timber structural members, and/or research standard models with locally relevant environmental considerations. Letter grading. Mr. Hazard (W)

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

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


140. Structural Components and Systems Test ing Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Enforced requis ite: course 142. Comparison of experimental results with analytical results and code requirements to assess accuracy of beam and slab systems. Quasi-static tests focus on assessment of element or subsystem stiffness, strength, and deformation capacity, whereas dynamic tests focus on assessment of period, mode shape, and damping. Development of communication skills through preparation of laboratory reports and oral presentations. Letter grading. Mr. Wallace (Not offered 2020-21)
istic green infrastructures that would not only mitigate environmental impact of clay material, but also be resilient under extreme weather conditions expected during climate change. Concurrently scheduled with course C259. Letter grading. Mr. Mohanty (Sp)

164. Sustainable Waste Management. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Required course: course C153. Introduction to environmental engineering. Management of solid wastes, some of which are hazardous, is integral part of infrastructure development, and it is required to achieve environmental sustainability. Study of all aspects of hazardous and municipal solid waste management technologies with particular emphasis on reuse of some of these by applications in energy production. Students are expected to integrate economic, environmental, regulatory, policy, and technical considerations into development of engineering designs of sustainable waste management. Student teams design sustainable remediation or waste management plans. Letter grading.

Mr. Stolzenbach (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 nanoscience and environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include three multidisciplinary areas: (1) physical, chemical, and biological properties of nanomaterials, (2) transport, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nanotechnology for energy and water production, plus environmental protection, monitoring, and remediation. Letter grading. Ms. Mahendra (W)

M166. Environmental Microbiology. (4) (Same as Environmental Health Sciences M166.) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 153. Microbial cell and its metabolic capabilities, microbial genetics and its potentials, growth of microbes and kinetics of growth, microbial ecology and diversity, microbiology of wastewater treatment, probing of microbes, public health microbiology, pathogen control. Letter grading. Ms. Mahendra (W)

M166L. Environmental Microbiology and Biotechnology Laboratory. (1) (Same as Environmental Health Sciences laboratory.) Two hours; outside study, two hours; Corequisite: course M166. General laboratory practice within environmental microbiology, sampling of environmental samples, classical and molecular microbiological techniques for enumeration of microbes from environmental samples, techniques for determination of microbial activity in environmental samples, laboratory setups for studying environmental microbiology. Letter grading. Ms. Mahendra (Not offered 2020-21)

170. Introduction to Construction Management. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Introduction to construction engineering theory, management, and techniques. Implementation of exercises from academic texts and real project case studies. Discussion of building systems, building components, project delivery methods, document control, critical path method scheduling, labor management, quality management, estimating, sustainability, and cost control. 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 students and Public Affairs graduate students. General characteristics of transportation systems, including streets and highways, rail, transit, air, and water. Capacity considerations, including planning, design, and operations. 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; discussion, two hours; outside study, six hours. Designed for juniors/senior and public affairs graduate students. Applications of traffic safety improvements, highway capacity analysis, signal design and timing, and intelligent Transportation Systems concepts, and traffic interface with railroads, urban transit, bicyclists, and pedestrians. Students analyze local roadway and freight/cargo transportation network and present recommendations to local public agency officials. Letter grading. Mr. Brandenberg (F)

C182. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: courses C104, C105, Materials Science 104. Correlation, analysis, and metrication of aspects of pavement design, including materials selection and traffic loading and volume. Emphasis on 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 C282. Letter grading. Mr. Sant (W)

188. Special Courses in Civil and Environmental Engineering. (4) Lecture, to be arranged; discussion, to be arranged (when scheduled); outside study, to be arranged. Special topics in civil engineering for undergraduate students taught on experimental or temporary basis, such as those taught by resident and visiting faculty members. May be repeated for credit with topic or instructor change. Letter grading. Mr. Bauchy (Sp)

190. Professional Practice. (2) Lecture, two hours; outside study, three hours. Required course from 121, 141, 142, 151, 155 (may be taken concurrently). Sustainability in design I - U. Introduction to laboratory and computational simulations at scale relevant to targeted problems. Letter grading. Mr. Burton (F)

194. Research Group Seminars: Civil and Environmental Engineering. (2 to 8) Seminar, two to 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. Mr. Bauchy (W,Sp)

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

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, environmental materials, structural engineering, and environmental mechanics. May be repeated for credit. S/U grading. (F,W)

204. Structure, Processing, and Properties of Civil Engineering Materials. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Discussion of aspects of cement and concrete materials, including manufacture of cement and production of concrete. Aspects of cement composition and basic chemical reactions, microstructure, properties of plastic and hardened concrete, chemical admixtures, and quality control and testing. Development and testing of fundamentals for complete understanding of overall response of all civil engineering materials. By end of term, successful utilization of fundamental materials science as applied to understanding, explain, and analyze engineering performance of civil engineering materials. Concurrently scheduled with course C104. Letter grading.


206. Modeling and Simulation of Civil Engineering Materials, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 121, 220, 223, Physics 1A, 1B, 1C, Fundamental examination of mechanical properties of civil engineering materials, with focus on practical examples and applications so students can independently run simulations at scale relevant to targeted problems. Letter grading. Mr. Bauchy (Sp)

207. Advanced Soil Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Stress distribution. Bearing capacity, settlement of shallow foundations, including spread footings and mats. Performance of driven pile and drilled shaft foundations under vertical and lateral loading. Construction considerations. Letter grading. Mr. Brandenberg (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-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 actions, cross-strain and pore water pressure behavior, shear moduli and damping, cyclic settlement and concept of volumetric cyclic threshold shear strain. Introduction to modeling of cyclic properties. Letter grading. Mr. Vucetic (Not offered 2020-21)

223. Slope Stability and Earth Retention Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 120, 121, 220. Basic concepts of stability of earth slopes, including shear strength, des- sign charts, limit equilibrium analysis, seepage analysis, staged construction, and rapid drawdown. Theory of earth pressures behind retaining structures, wall slope stability, and anchored 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. Requisite: course 120. In-depth study of soil behavior under cyclic and monotonic loads. Relationships between stress, strain, pore water pressure, and volume change in range of very small and large strains. Concept of normalized static and cyclic soil behavior. Cyclic degradation and liquefaction of saturated soils. Cyclic settlement of partially saturated and dry soils. Concept of the 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. Vucetic (F)

225. Geotechnical Earthquake Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: courses 220, 245 (may be taken concurrently). Analysis of forces on, and failures of, ground and surface structures; ground motion; soil-structure interaction; seismic design of buildings and other structures; and seismic safety. Letter grading. Mr. Stewart (W)

226. Geoenvironmental Engineering. (4) Lecture, four hours; outside study, eight hours. Requisite: course 120. Field of geoenvironmental engineering involves application of geotechnical principles to environmental problems. Topics include environmental 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 elasticity and plasticity theories. Special attention is given to numerical applications and identification of modeling concerns such as instability, bifurcation, nonexistence, and nonuniqueness of solutions. Letter grading. Mr. Ju, Mr. Mal (Not offered 2020-21)

228. 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 properties of soil and rock. Landform changes occur in response to dynamic processes, including changes in climate, slope formation, fluvial (river) dynamics, coastal and marine dynamics, and deep-seated processes like volcanism, 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 (Not offered 2020-21)

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 165A. Linear elasticity. Kinematics of deformation, material and spatial coordinates, deformation gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola stress tensors, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoeffect; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (F)

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 laws, Cauchy and Piola stress tensors, Cauchy equations of motion, balance of energy, stored energy; constitutive relations, elasticity, hyperelasticity, thermoeffect; linearization of field equations; solution of selected problems. Letter grading. Mr. Ju, Mr. Mal (W)


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


235A. Advanced Structural Analysis. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 135A. Recommended: course 135B. Review of matrix methods and displacement analysis of structures. Static and dynamic analysis of beams and frame structures; analysis of beams, frame, and shell structures. Introduction to finite element analysis. Letter grading. Mr. Burton, Mr. Taciroglu (F)

235B. Finite Element Analysis of Structures. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Requisite: course 130, 235A. Finite element formulations for deformable systems; solution methods for linear systems; analysis of structural systems with one-dimensional elements; introduction to variational calculus; discrete element methods; finite element methods for membrane, plate, shell structures; instability effects. Letter grading. Mr. Taciroglu (W)

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


237A. Dynamics of Structures. (4) (Same as Mechanical and Aerospace Engineering M256A.) Lecture, four hours; outside study, eight hours. Requisite: course 235A. Channels of dynamic and static response. Determination of normal modes and frequencies by differential and integral equation solution techniques. Analysis of dynamic systems and steady state response. Emphasis on derivation and solution of governing equations using matrix formulation. Letter grading. Mr. Ju, Mr. Taciroglu (W)


C239. Elementary Structural Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisite: course 135B. Basic structural dynamics course for civil engineering students. Elastic free and fixed end single degree of freedom systems, introduction to response history and response spectrum analysis approaches for single and multidegree of freedom systems. Axial, bending, and torsional vibration are concurrently studied with course C137. Letter grading. Mr. Taciroglu (F)


243A. Behavior and Design of Reinforced Concrete Structural Elements. (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 (Sp)

245A. Behavior and Design of Reinforced Concrete Structural Systems. (4) Lecture, four hours; outside study, six hours. Requisite: courses 243A, 246. Information on response behavior of reinforcing elements to earthquake ground motions. Topics include use of elastic and inelastic response spectra, role of strength, stiffness, and ductility in design, use of pre- prescribed versus performance-based design methodologies, and application of elastic and inelastic analysis techniques for new and existing construction. Letter grading. Mr. Wallace (Sp)

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

247. Earthquake Hazard Mitigation. (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. Stewart (W)

248. 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 Fourier spectra. Response of structures to ground motions due to earthquakes. Computational methods to evaluate structural response. Response analysis, including evaluation of contemporary design standards. Limitations due to idealizations. Letter grading. Mr. Taciroglu, Mr. Wallace (W)

249. Earthquake Hazards in Civil Engineering. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 130, and M237A or 246. Concept of seismic isolation, linear theory of base isolation, visco-elastic and hysteretic behavior, elas- tometric bearings under compression and bending, buckling of bearings, sliding bearings, passive energy
dissipation devices, response of structures with isolation and passive energy dissipation devices, static and dynamic analysis procedures, code provisions and design methods for seismically isolated structures. Letter grading. Ms. Zhang (Sp)

250A. Surface Water Hydrology. (4) Lecture, four hours; outside study, six hours. Requisite: course 250A, 250C. Introduction to basic concepts of classical and Bayesian estimation theory for purposes of hydrologic data assimilation. Applications geared toward assimilating disparate observations into dynamic models to resolve hydroclimatic and environmental problems. Letter grading. Mr. Margulis (Not offered 2020-21)

252. Engineering Economic Analysis of Water and Environmental Planning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Emphasis on management of water quantity. Letter grading. Mr. Yeh (Not offered 2020-21)


254A. Environmental Aquatic Inorganic Chemistry. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 251A, 251C. Chemical composition and history of Earth’s atmosphere; biogeochemical cycles of key atmospheric constituents; basic photochemistry of tropospheric gases; and stratospheric and stratospheric mechanisms in aqueous and gaseous chemical processes; air pollution chemistry and climate. S/U or letter grading. (F)

255. Physical and Chemical Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 255A, 255A. Fundamentals of environmental engineering microbiology; kinetics of microbial growth and biological oxidation; applications for activated sludge, gas transfer, disinfection, oxidation, and membrane processes. Letter grading. Mr. Hoek (Sp)

255B. Biological Processes for Water and Wastewater Treatment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 254A, 255A. Overview of mass transfer, chemical reaction engineering, coagulation and flocculation, granular filtration, sedimentation, carbon adsorption, gas transfer, disinfection, oxidation, and membrane processes. Letter grading. Mr. Stenstrom (W)

2561. Colloidal Phenomena in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 250A, 253. Phenomena and mechanisms of hydrodynamic dispersion, governing equations of mass transport in porous media, various analytical and numerical solutions, determination of dispersion parameters by laboratory and field experiments, biological and reactive transport in multiphase fluid, remediation design, software packages and applications. Letter grading. Mr. Yeh (Not offered 2020-21)

256A. Membrane Separations in Aquatic Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Applications of membrane separation technologies to desalination, water and air purification, and waste treatment and water reuse systems. Discussion of reverse osmosis, ultrafiltration, electro dialysis, and ion exchange technologies from both practical and theoretical standpoints. Letter grading. Mr. Hoek (Sp)

259. Green Infrastructure. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 150, 153. Overview of fundamental science, engineering, and ecological principles to designing green infrastructure for stormwater management. Students design green infrastructure based on current practices, perform engineering calculations to calculate its performances, and develop critical thinking skills needed to design innovative or future green infrastructures that would not only mitigate adverse impact of climate change, but also remain resilient under future conditions expected during climate change. Concurrently scheduled with course C159. Letter grading. Mr. Mohanty (Mar)

260. Advanced Topics in Hydrology and Water Resources. (4) Lecture, four hours; outside study, eight hours. Requisite: course 254A. Geochemical modeling is important tool for predicting environmental impacts of contamination. Hands-on experience in modeling using geochemical software packages commonly found in environmental consulting industry to gain better understanding of governing geochemical principles pertaining to movement and transformation of contaminants. Types of modeling include speciation, mineral solubility, surface comm
plication, reaction path, inverse mass balance, and reactive transport modeling. Case studies involve acid mine drainage, nuclear waste disposal, bioavailability and risk assessment, mine tailings and mining waste, deep well injection, landfill leachate, and microbial respiration. Research/modeling projects required. Letter grading. Ms. Jay (Not offered 2020-21)

C282. Rigid and Flexible Pavements: Design, Materials, and Serviceability. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Correlation, analysis, and prediction 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.

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

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

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

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

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

597A. Preparation for 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.

597B. Preparation for PhD Preliminary Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate civil engineering students. S/U grading.

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

598. Research for and Preparation of 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.

599. 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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Song-Chun Zhu, Ph.D.

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Wesley W. Chu, Ph.D.
Michael G. Dyer, Ph.D.
Milos D. Ercegovac, Ph.D.
Sheila A. Greibach, Ph.D.
Leonard Kleinrock, Ph.D.
Allen Klinger, Ph.D.
Lawrence P. McNamee, Ph.D.
Richard R. Muntz, Ph.D.
D. Stott Parker, Jr., Ph.D.
Judea Pearl, Ph.D. (Chancellor’s Professor Emeritus)
David A. Rennels, Ph.D.
Carlo A. Zaniolo, Ph.D. (Norman E. Friedman Professor Emeritus of Knowledge Sciences)

Associate Professors

Jason Ernst, Ph.D.
Raghup Meka, Ph.D.
Alexander Sherstov, Ph.D.
Yizhou Sun, Ph.D.
Yuval Tamar, Ph.D.
Guy Van den Broeck, Ph.D.
Harry Xu, Ph.D.

Assistant Professors

Kai-Wei Chang, Ph.D.
Alyson K. Fletcher, Ph.D.
Quanquan Gu, Ph.D.
Cho-Jui Hsieh, Ph.D.
Baharan Mirzazoleiman, Ph.D.
Ravi Nataravali, Ph.D.
Anthony J. Nowatzi, Ph.D.
Nanyun Peng, Ph.D.
Omid Salehi-Abari, Ph.D.
Sriram Sankararaman, Ph.D.
Fabien Scalzo, Ph.D. in Residence

Senior Lecturers S.O.E.

Paul R. Eggert, Ph.D.
David A. Smallberg, 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 Professors

Carey S. Nakenberg, M.S.
Giovanni Pau, Ph.D.
Ramin Ramezani, Ph.D.

Adjunct Assistant Professor

Alexander Afanasiev, 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 Samuei 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 undergraduate program is accredited by the Engineering Accreditation Commission and the Computing Accreditation Commission of ABET. The computer science and engineering undergraduate program educational objectives are that our alumni (1) make valuable technical contributions to design, development, and production in their practice of computer science and related engineering or application areas; (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 computer engineering undergraduate program educational objectives are that our alumni (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; and (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. 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 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 as part of 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, MS1A; 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, 11B, 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, 170E, or Statistics 100A; one capstone design course (Computer Science 152B); a minimum of 4 units of at least one elective course selected from Electrical and Computer Engineering 101A through M185; a minimum of 12 units of at least three elec-
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.

Computer Engineering B.S.
Capstone Major
The computer engineering 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 networking 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 M16C), M152A (or Electrical and Computer Engineering M16L), 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 information on UC, school, and general education requirements, see Requirements 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 (17 units minimum):* Computer Science 32 or Program in Computing 10C, Life Sciences 3 or 7A, Mathematics 33A, 61.

*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, 153B, 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, 170E, 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.

**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, even 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 Samuels 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 (17 units minimum):* Computer Science 32 or Program in Computing 10C, Life Sciences 3 or 7A, Mathematics 33A, 61.

*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, 153B, 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, 170E, 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.
If students apply any of Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, 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 26.

The following introductory information is based on 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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, 110M, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 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 requirement 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 Schoolwide Programs.

Written and Oral Qualifying Examinations

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

After passing the preliminary examination and coursework for the major and minor fields, the student should form a doctoral committee and prepare to take the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, must hold appointments in the department. The remaining member must be a UCLA faculty member in another department. The nature and content of the oral qualifying examination are at the discretion of the doctoral committee but ordinarily include a broad inquiry into the student’s preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Fields of Study

Artificial Intelligence

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

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

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

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

Computational Systems Biology

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

Core coursework is concerned with the methods and tools development for computational, algorithmic, and dynamic systems network modeling of biological systems at molecular, cellular, organ, whole organism, or population levels—and leveraging them in biosystem and bioinformatics applications. Methodological studies include bioinformatics and systems biology modeling, with 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; neuro-systems, imaging and remote sensing systems, robotics, learning and knowledge-based systems, visualization, and virtual clinical environments. Typical research areas with most of the technical 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 pre-scheduled allocation. On-demand allocation is found to be effective, since it takes advantage of statistical averaging effects. It comes in many forms in computer networks and is known by names such as asynchronous time division multiplexing, packet switching, frame relay, random access, and so forth.

Computer Science Theory

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

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

Emphasis of Computer Science Theory

Computer science theory emphasizes

- Design and analysis of algorithms
- Distributed and parallel algorithms
- Models for parallel and concurrent computation
- Online and randomized algorithms
- Computational complexity
- Automata and formal languages
- Cryptography and interactive proofs

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 smart phones 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 formulated for efficient implementation where regularity of structure and simplicity of interconnections are required.

4. Computer-aided design of VLSI circuits and systems is an active research area that develops techniques for the automated synthesis and analysis of large-scale systems. Topics include high-level and logic-level synthesis, technology mapping, physical design, interconnect modeling, and optimization of various VLSI technologies such as full-custom designs, standard cells, programmable logic devices (PLDs), multichip modules (MCMs), system-on-a-chip (SoCs) that are used in a wide range of applications from IoTs to data centers.

5. VLSI architectures and implementation is an area of current interest and collaboration between the Electrical and Computer Engineering and Computer Science departments that addresses the impact of large-scale integration on the issues of computer architecture. Application of these systems in medicine and health care, multimedia, and finance is being studied in collaboration with other schools on campus.

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

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

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

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

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

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

Facilities
Departmental laboratories and centers for instruction and research include:

Artificial Intelligence Laboratories

Automated Reasoning Group

Adnan Y. Darwiche, Director

The Automated Reasoning Group focuses on research in automated reasoning (logical and probabilistic) and machine learning, including their application to problems in science and engineering. On the theoretical side, the group focuses on tractable circuit representations and models that combine logic and probability, in addition to new models for machine learning that can integrate background knowledge. On the practical side, the group builds scalable reasoning and learning systems that can scale to real-world problems.

Cognitive Systems Laboratory

Judea Pearl, Director

The Cognitive Systems Laboratory targets research areas concerned with evidential reasoning, the distributed interpretation of multisource data in networks of partial beliefs; learning, the structuring and parameterization of links in belief networks to form a representation consistent with a stream of observations; constraint processing, including intelligent backtracking, learning while searching, temporal reasoning, etc.; graphoids, the characterization of informational dependencies, and their graph representations; and default reasoning, use of qualitative probabilistic reasoning to draw plausible and defeasible conclusions from incomplete information.

Computational Machine Learning Laboratory

Cho-Jui Hsieh, Director

The Computational Machine Learning Laboratory conducts research on making machine learning algorithms more efficient, scalable, robust, and interpretable. The current focuses include large-scale training algorithms, robustness evaluation and defense, AutoML, machine learning model verification, and reinforcement learning.
Large-Scale Machine Learning Group (BigML)
Baharan Mirzasoleiman, Director
The Large-Scale Machine Learning Group conducts research in machine learning focused on designing new methods that enable efficient learning from massive datasets. More specifically, the group designs techniques that can gain insights from the underlying data structure by utilizing complex and higher-order interactions between data points. The extracted information can be used to efficiently explore and robustly learn from datasets that are too large to be dealt with by traditional approaches. The developed methods have immediate application to high-impact problems where massive data volumes prohibit efficient learning and inference, such as huge image collections, recommender systems, Web and social services, video, and other large data streams.

Statistical and Relational Artificial Intelligence Laboratory (StarAI)
Guy Van den Broeck, Director
The StarAI Laboratory performs research on machine learning (statistical relational learning, tractable learning), knowledge representation and reasoning (graphical models, lifted probabilistic inference, knowledge compilation), applications of probabilistic reasoning and learning (probabilistic programming, probabilistic databases), and artificial intelligence in general.

Statistical Machine Learning Laboratory
Quanquan Gu, Director
The Statistical Machine Learning Laboratory conducts research on machine learning, optimization, and high-dimensional statistical inference. Its focus is on development and analysis of nonconvex optimization algorithms for machine learning to understand large-scale, dynamic, complex, and heterogeneous data; and on building the theoretical foundations of deep learning and deep reinforcement learning.

Computational Systems Biology Laboratories
AI in Imaging and Neuroscience Research Laboratory
Fabien Scalzo, Director
The AI in Imaging and Neuroscience Research Laboratory aims to develop machine learning algorithms for medical images, with a special focus on vascular diseases and cancer. An important component of its research is development of computational and predictive models for neurovascular diseases based on multimodal medical imaging, including magnetic resonance imaging (MRI), computed tomography (CT), digital subtraction angiography (DSA), and transcranial Doppler ultrasound (TCD). By building models that can identify predictive factors of the patient outcome, they can help tailor treatment and improve the odds of a better recovery.

Big Data and Genomics Laboratory
Eran Halperin, Director
The Big Data and Genomics Laboratory aims to improve understanding and treatment of human disease by analysis of big data collected in relation to diseases. The main focus of the laboratory has been development of methods for analysis of genomic data—including genetics, epigenetics, RNA, and microbiome data; as well as medical records, images, and waveforms of UCLA Health medical center patients. The methods developed are typically standalone tools, often used by other researchers for analysis of specific diseases. The methodology involves a combination of machine learning, optimization algorithms, combinatorial optimization, and classical and Bayesian statistics.

Biocybernetics Laboratory
Joseph J. DiStefano III, Director
The interdisciplinary research of the Biocybernetics Laboratory 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 methodological 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
The Computational Genetics Laboratory is comprised of a computational genetics group affiliated with both the Computer Science and Human Genetics departments. Research interests are in computational genetics, bioinformatics, computer science, and statistics. The laboratory focuses on developing techniques for solving the challenging computational problems that arise in attempting to understand the genetic basis of human disease.

Machine Learning and Genomics Laboratory
Sriram Sankaranarayanan, Director
The interdisciplinary Machine Learning and Genomics Laboratory research group is affiliated with UCLA departments of Computer Science, Human Genetics, and Computational Medicine. It is broadly interested in questions at the intersection of computer science, statistics, and biomedicine. It develops statistical and computational methods to make sense of complex, high-dimensional datasets generated in the fields of genomics and medicine, to answer questions ranging from how humans have evolved, to what the biological underpinnings of diseases are, to how we can improve the diagnosis and treatment of disease. A major focus of this research is understanding and interpreting human genomes. The biological questions of interest center around understanding how evolution shapes human genes, and how they modulate complex traits that include common diseases. The laboratory develops and extends tools from a diverse set of disciplines including machine learning, algorithms, optimization, high-dimensional statistics, and information theory. It also applies these tools to high-dimensional genomic and medical datasets that are publicly available or being generated by laboratory collaborators.

Computer Systems Architecture Laboratories
Architecture Specialization Laboratory (PolyArch)
Anthony J. Nowatzki, Director
The Architecture Specialization Laboratory studies how to redesign computer architectures and accelerators to continue improving performance and energy efficiency, even while technology scaling reaches its physical limits. Broadly, its approach is to consider how to reform traditional hardware/software abstractions to convey rich information that can make building efficient micro-architectures possible. These changes necessitate codeign of ISAs, architecture, execution models, and compilers.
Concurrent Systems Laboratory
Yuval Tamir, Director
The Concurrent Systems Laboratory conducts research on the design, implementation, and evaluation of computer systems that use state-of-the-art technology to achieve high performance and high reliability. Projects involve software, hardware, and networking. The focus is typically on parallel and distributed systems, and often involves fault tolerance.

Digital Arithmetic and Reconfigurable Architecture Laboratory
Milos D. Ercegovac, Director
The Digital Arithmetic and Reconfigurable Architecture Laboratory is used for fast digital arithmetic (theory, algorithms, and design) and numerically intensive computing on reconfigurable hardware. Research includes floating-point arithmetic, online arithmetic, application-specific architectures, and design tools.

eHealth Research Laboratory (ER Lab)
Majid Sarrafzadeh, Director
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
The VAST Laboratory investigates cutting-edge research topics at the intersection of VLSI technologies, design automation, architecture, and compiler optimization at multiple scales, from micro-architecture building blocks to heterogeneous compute nodes and scalable data centers. Currently, the laboratory is focused on architecture and design automation for emerging technologies; and customizable domain-specific computing with applications to multiple domains such as imaging processing, bioinformatics, data mining, and machine learning.

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

Computer Graphics and Vision Laboratory (GraViLab)
Demetri Terzopoulos, Director
The Computer Graphics and Vision Laboratory engages in a broad spectrum of visual computing research unifying computer graphics (image synthesis), computer vision (image analysis), and related fields; with emphasis on geometric, physics-based, learning-driven, and artificial intelligence/life modeling and simulation. Major research interests include biomimetic simulation of humans and other animals, from biomechanics to sensorimotor control to intelligence; and image/video analysis combining (deep) learning and modeling paradigms, especially for application to medicine and health care.

UCLA Collective on Vision and Image Sciences
The Collective on Vision and Image Sciences brings together researchers from multiple departments at UCLA, including Brain Mapping, Computational and Systems Biology, Computer Science, Image Informatics, Mathematics, Neuroimaging, Psychology, Radiology, and Statistics.

UCLA Vision Laboratory
Stefano Soatto, Director
Researchers at the Vision Laboratory 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 help understand the effects of climatic 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)
The Information and Data Management Group is a collaboration of all UCLA faculty from this 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.

Natural Language Processing Group
Kai-Wei Chang, Director
The Natural Language Processing Group focuses on developing reliable machine learning solutions for processing natural languages. Specifically, it targets design of models and algorithms, and learning mechanisms to improve the generalization ability of natural-language processing models such that they can generalize across unseen tasks, unseen inputs, and low-resource languages.

Peng’s Language Understanding and Synthesis Laboratory (PLUS)
Nanyun Violet Peng, Director
The PLUS Laboratory is a collection of researchers working on natural language processing. The laboratory’s mission is to push the frontier of natural language generation towards coherent, controllable, and creative narrative generation through natural language understanding and common-sense reasoning. Along these lines, the laboratory develops novel machine learning models, specifically deep structured models and graph neural networks to cope with challenging natural language-related problems.
Web Information Systems Laboratory
Carlo A. Zaniolo, Director
The Web Information Systems Laboratory 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 Design Automation Laboratory
George Varghese, Director
The Network Design Automation Laboratory focuses on research in this field, an effort to build a comprehensive set of design tools for networks inspired by electronic design automation for chips. A major focus is analysis and synthesis of router configuration files to avoid major outages that frequently cripple major service providers. This work involves development of new tools inspired by other fields such as programming languages, hardware design, and data mining. It is analysis and synthesis of router configuration files to avoid major outages that frequently cripple major service providers. This work involves development of new tools inspired by other fields such as programming languages, hardware design, and data mining. It is targeted to incorporate the special structure and challenges of networks. It involves collaboration with multiple disciplines such as programming languages, systems, and network debugging; and includes other UCLA faculty.

Network Systems Laboratories
Intelligent Sensing and Connectivity Laboratory (ICON Lab)
Omid Abari, Director
The group conducts research in the area of networked systems, with applications to the Internet of things (IoT). It develops software-hardware systems that deliver ubiquitous sensing, efficient computing; and wireless communication at scale. Its research borrows techniques from diverse areas including computer networks, machine learning, signal processing, hardware design, and HCI to develop new algorithms and technologies that enable smart environments.

Internet Research Laboratory (IRL)
Lixia Zhang, Principal Investigator
The Internet Research Laboratory mission is to help the Internet grow. Its research efforts focus on design and development of network architecture and protocols, and the challenges in building secure networks and systems. Its past work has turned into Internet standards and successful startups. Since 2010, the laboratory has been working on design and development of named data networking (NDN), a new Internet architecture.

Networked and Application Systems Group (NAS)
Ravi Netravali, Director
The group is focused on building practical systems to improve the performance and ease of debugging large-scale distributed applications. Such applications include web pages, mobile apps, video streaming and analytics systems, data analytics platforms, and more. The group uses a cross-layer methodology that aims to understand the impact of decisions at different layers in the end-to-end system; and designs solutions that incorporate fundamental principles at the network, operating system, and application vantage points.

UCLA Connection Laboratory
Leonard Kleinrock, Director
The Connection Laboratory offers an environment to support advanced research in technologies at the forefront of all things regarding networking and connectivity, and will deliver the benefits of that research to society globally. The laboratory’s broad-based agenda enables faculty, students, and visitors to pursue research challenges of their own choosing, without externally imposed constraints on scope or risk. It draws inspiration from the foundational role of UCLA as the birthplace of the Internet. With its open inclusive structure, the laboratory will help to realize the vision of creating high-leverage technologies, as was accomplished years ago with the Internet.

Wireless Networking Group (WiNG)
Songwu Lu, Director
The Wireless Networking Group’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
Harry Xu, Director
The Large-Scale Systems Group builds systems to improve the efficiency, scalability, reliability, and security of modern applications and workloads. These include graph analytics, video analytics, machine learning, smart contracts, etc. The group’s solutions cross multiple layers of the compute stack, spanning the areas of programming languages, compilers, operating systems, runtime systems, distributed systems, networking, and computer architecture.

Software Engineering and Analysis Laboratory (SEAL)
Minyung Kim, Director
The Software Engineering and Analysis Laboratory conducts research in software engineering, in particular debugging and testing for big data systems and automated tools for data science and ML-based systems. Its overall goal is to improve software engineering productivity and correctness. To achieve it, the laboratory designs scalable software systems, software analysis algorithms, and automated development tools. It also conducts user studies with software engineers, and carries out statistical analysis of open-source project data to allow data-driven decisions for designing novel software engineering tools. With expertise in software evolution, the laboratory is known for its research on code clones—code duplication detection, management, and removal solutions. The laboratory is a leader in creation and definition of the emerging area where software engineering and data science intersect. It has conducted the most comprehensive study of industry data scientists, and developed automated debugging and testing technologies for widely-used big data systems such as Apache Spark. Through tech-transfer, several companies have used SEAL research on interactive code clone search and big data analytics debugging technologies.
Software Systems Group
(Multiple Faculty)
The Software Systems 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)
The Center for Autonomous Intelligent Networked Systems was established in 2003 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)
Jason Cong, Director
The Center for Domain-Specific Computing looks beyond parallelization and focuses on domain-specific customization as a disruptive technology to bring orders-of-magnitude power-performance efficiency improvement to application domains. CDSC develops a general methodology for creating novel, customizable computing platforms, and associated compilation tools and runtime management environment to support domain-specific computing. Its 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 for customizable heterogeneous platforms, including multicore CPUs, many-core GPUs, and FPGAs; and a general, reusable methodology for customizable computing applicable across domains. By combining these capabilities, the goal is to deliver a supercomputer-in-a-box or -in-a-cluster, customizable to an application domain to enable disruptive innovations therein. This approach has been successful in medical image processing, precision medicine, and machine learning. Originally funded by a $10 million National Science Foundation (NSF) Expeditions in Computing award, in 2014 CDSC received $3 million from Intel Corporation with matching NSF InTrans program support. CDSC research is also supported by SRC JUMP and several industrial partners.

Center for Encrypted Functionalities
Amit Sahai, Director
The Center for Encrypted Functionalities was established in 2014 through an NSF Secure and Trustworthy Cyberspace (SaTC) Frontier Award. The center tackles the deep and far-reaching problem of general-purpose software obfuscation. The goal of obfuscation is to enable software that can keep secrets: software that makes use of secrets, but such that they remain hidden even if an adversary can examine the software code in its entirety and analyze its behavior as it runs. The center is headquartered at UCLA with partners at Columbia, Johns Hopkins, and Stanford universities, and University of Texas at Austin.

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

The center has raised federal, state, and private-sector funding, including collaboration with Israel through multiple U.S.-Israel 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 Scalable Analytics 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. (Biomedical Engineering), 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 perfor-
mance, 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 colleges 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 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, figures 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 Cho, Ph.D. (Stanford, 2002)

Databases, web technologies, information discovery and integration

Jingdong Cong, Ph.D. (U. Illinois, 2000)

Electronic data automation, energy-efficient computing, customized computing for big-data applications, highly scalable algorithms, quantum computing

Adnan Y. Darwiche, Ph.D. (Stanford, 1993)

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

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

Dynamic biosystems modeling methodology, simulation, clinical therapy and experiment design optimization; pharmacokinetics (PK), pharmacodynamics (PD), physiologically based PK (PKPD), epidemiological modeling

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

Bioinformatics, genetics, genomics, machine learning


Problem solving, heuristic search, planning in artificial intelligence

Songwu Lu, Ph.D. (U. Illinois, 1999)

Integrated-service support over heterogeneous networks, e.g., mobile computing environments, Internet and ActiveX; 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

* Ralf Oosterveld, Ph.D. (MIT, 1992)

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

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

Compiler, embedded systems, programming languages

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

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

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

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

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

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

Majid Sarrafzadegan, 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

Mani B. Srivastava, Ph.D. (U. Berkeley, 1992)

IoT, edge computing, and human-computer-physical systems; ML/AI for real-time and resource-constrained systems; security and privacy; applications in mobile health and smart environments

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

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

Mihaela 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

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


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

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

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

Elmo P. Cardenas, Ph.D. (UCLA, 1969)

Database management, distributed heterogeneous and multimedia (text, image/picture, video, voice) systems, information systems planning and development methodologies, software engineering, medical informatics, legal and intellectual property issues


Communication, computation theory and practice, algorithms and complexity, discrete system theory, developmental and probabilistic systems

Wesley W. Chu, Ph.D. (Stanford, 1966)

Distributed computing, distributed database, memory management, computer communications, performance measurement and evaluation for distributed systems and multiaccess packet-switched systems

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

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

* Also Professor of Mathematics
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 (excludes this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper-Division Course

199. Directed Research in Bioinformatics. (2 to 4) Tutorial, six to 12 hours. Limited to juniors/seniors. Supervised individual research under guidance of faculty mentor. Culminating paper required. May be repeated for credit. Individual contract required. Letter grading.

Computer Science

Lower-Division Courses

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

9. 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.

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.

Adjoint Associate Professors

Carey S. Nachenberg, M.S. (UCLA, 1995) Anti-virus and intrusion detection technology


Ramin Ramezani, Ph.D. (Imperial College, London, England, 2014) Logic and AI, inductive logic programming, constraint solving, machine learning, combined reasoning, signal processing

Adjoint Assistant Professor

Alexander Afanasyev, Ph.D. (UCLA, 2013) Named data networking (NDN), information-centric networking (ICN)

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

Alan Kay, Ph.D. (U. Utah, 1969) Object-oriented programming, personal computing, graphical user interfaces


Adjunct Associate Professors

Carey S. Nachenberg, M.S. (UCLA, 1995) Anti-virus and intrusion detection technology


Ramin Ramezani, Ph.D. (Imperial College, London, England, 2014) Logic and AI, inductive logic programming, constraint solving, machine learning, combined reasoning, signal processing

Adjoint Assistant Professor

Alexander Afanasyev, Ph.D. (UCLA, 2013) Named data networking (NDN), information-centric networking (ICN)

Mr. Stahl, Mr. Smallberg (F,Sp)


Mr. Nachenberg, Mr. Smallberg (W,Sp)

33. Introduction to Undergraduate Organizations, (1) Lecture, four hours; discussion, two hours; outside study, nine hours. Enforced requisite: course 32. Introductory course on computer architecture, assembly language, operating systems fundamentals, number systems, machine language, and assembly language. Procedure calls, stacks, interrupts, and traps. Assemblers, linkers, and loaders. Operating systems concepts; processes and process management, input/output (I/O) programming, memory management, file systems. Letter grading.  

Mr. Nowatzki, Mr. Reiman (F,Sp)

35L. Software Construction Laboratory, (3) Laboratory, four hours; outside study, five hours. Requisite: course 31. Fundamentals of commonly used software tools and environments, particularly open-source tools to be used in upper-division computer science courses. Letter grading.  

Mr. Eggert (F,Sp)

M51A. Logic Design of Digital Systems, (4) (Same as Electrical and Computer Engineering M16.) 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 combinational and sequential systems. Number systems and arithmetic algorithms. Error control codes for digital information. Letter grading.  

Mr. Abari, Mr. Korf, Mr. Ramezani (F,Sp)

97. Variable Topics in Computer Science, (1 to 4) Lecture, discussion, zero to four hours; outside study, zero to four hours. Designed for freshmen/sophomores. Variable topics in computer science not covered in regular computer science courses. May be repeated once for credit with topic or instructor change. Letter grading.  

Mr. Korf (F,Sp)

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

Mr. Korf (F,Sp)

Upper-Division Courses


Mr. Reihler, Mr. Xu (F,Sp)

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

Mr. Sanadidi, Mr. Soatto (Not offered 2020-21)

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. Topics include wireless LANs (IEEE802.11) and ad hoc wireless and personal area networks (e.g., Bluetooth, ZigBee). Experimental project based on mobile radio-equipped devices (smart phones, tablets, etc.) as sensor platforms for personal applications such as wireless health, positioning, and environmental awareness, and experimental laboratory sessions included. Letter grading.  

(Not offered 2020-21)

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

Mr. Varghese (F,Sp)

M119. Fundamentals of Embedded Networked Systems Engineering, (4) Lecture and computer hours; (Same as Electrical and Computer Engineering M119.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Civil and Environmental Engineering 110 or Electrical and Computer Engineering 130A or 130T or Statistics 100A, course 118 or Electrical and Computer Engineering 132B, course 33. Design trade-offs and principles of operation of cyber physical systems such as devices and systems constituting Internet of Things. Topics include basic signal propagation and modeling, sensing, node architecture and operation, and applications. Letter grading.  

(Not offered 2020-21)

CM121. Introduction to Bioinformatics, (4) (Same as Chemistry CM160A.) Lecture, four hours; discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, Civil Engineering 110, Electrical Engineering 130A, 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 statistical methods, with emphasis on concepts and integrating computational and statistical techniques to analyze biological data. Focus on sequence analysis and algorithm design. Concurrently scheduled with course CM221. P/NP or letter grading.  

Mr. Sul (F)

CM122. Algorithms in Bioinformatics, (4) (Same as Chemistry CM160B.) Lecture, four hours; discussion, two hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, and one course from Biostatistics 100A, Civil Engineering 110, Electrical Engineering 130A, Mathematics 170A, or Statistics 100A. Course CM121 is not requisite to CM122. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving those problems using algorithmic techniques. Computational techniques include those from statistics and computer science. Concurrently scheduled with course CM222. Letter grading.  

CM124. Machine Learning Applications in Genet- ics, (4) (Same as Human Genetics CM124.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better, course 111, and one course from Civil Engineering 110, Electrical and Computer 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 history, technologies for obtaining genetic information, and genetic sequencing. Focus on formulating interdisciplinary problems as computational problems and then solving those problems using algorithmic techniques from statistics and computer science. Concurrently scheduled with course CM224. Letter grading.  

Mr. Halperin (W)

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

Mr. Burns, Mr. Elassar, Ms. Kim (F,Sp)

131. Programming Languages, (5) Lecture, four hours; laboratory; two hours; outside study, six hours. Enforced requisites: courses 33, 35L. Basic concepts in design and use of programming languages, including abstraction, modularity, control mechanisms, types, declarations, syntax, and semantics. Study of several different language paradigms, including functional, object-oriented, and logic programming. Letter grading.  

Mr. Eggert (F,Sp)


Mr. Palberg (F)

133. Parallel and Distributed Computing, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: courses 131, M151B. Distributed memory and shared memory parallel architectures; asynchronous parallel languages: MPI, Masse; primitives for parallel computation: specification of parallelism, interprocess communication and synchronization; design of parallel programs for scientific and distributed computing applications. Letter grading.  

Mr. Cong (W)

134. Distributed Systems, (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 32, M151B. Course covers fundamental concepts regarding design and implementation of distributed systems. Topics include synchronization (e.g., clock synchronization, logical clocks, vector clocks), failure recovery (e.g., checkpointing, primary-backup), consistency models (e.g., eventual, causal), consensus protocols (e.g., Paxos, Raft), distributed transactions, and lock. Students gain hands-on, practical experience through multiple programming assignments that work through steps of creating fault-tolerant, shared key/value store. Exploration of how these concepts have manifested in several real-world, large-scale distributed systems used by Internet companies like Google, Facebook, and Amazon. Letter grading.  

Mr. Palberg (F)
136. Introduction to Computer Security. (4) Lecture, four hours; outside study, six hours. Enforced requisite: course 118. Introduction to basic concepts of information security necessary for students to understand risks and mitigations associated with modern computing systems and systems. Topics include security models and architectures, security threats and risk analysis, access control and authorization/authentication, cryptography, network security, and legal implications of security. Letter grading. Mr. Reiher (W)

C137A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 131. How different programming language paradigms produce dramatically different ways of thinking about computation and offer trade-offs on many dimensions, such as modularity, expressiveness, and safety. Exploration of three major programming paradigms—functional, object-oriented, and logic programming—by prototyping implementations of languages in each. Analysis of prototypes to shed light on design and structural properties of each language and paradigm and to allow easy comparison against one another. Hands-on experience implementing new abstractions, both as stand-alone languages and as libraries in existing languages. Concurrent with courses C237A and C237B. Letter grading. Mr. Millstein (Not offered 2020-21)

C137B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced requisites: courses C137A. Study of various programming language design issues, 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. Concurrent with courses C237A and C237B. Letter grading. Mr. Millstein (Not offered 2020-21)


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 and first-hand experience with basic tools. Topics include basic Web architecture and protocol, XML and XML languages, associations between XML and relational models, information retrieval model and theory, security and user model, Web services and distributed transactions. Letter grading. Mr. Cho (Sp)

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, analysis, and description of patterns in large databases, association rules in large transaction databases, anomalies in massive databases), 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 service analysis. Letter grading. Ms. Sun, Ms. Wang (F)

M146. Introduction to Machine Learning. (4) (Same as Electrical and Computer Engineering M146). Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 33, and Civil and Environmental Engineering 110 or Electrical and Computer Engineering 131A or Mathematics 170A, 170E, or Statistics 100A. Introduction to breadth of data science. Foundations for modeling data sources, principles of operation of common tools for data analysis, and application of tools and models to data gathering and analysis. Topics include supervised and unsupervised classification, kernel methods, clustering, expectation maximization, principal component analysis, decision theory, reinforcement learning and deep learning. Letter grading. Mr. Srebro (W,Sp)

M151B. Computer Systems Architecture. (4) (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 M16. Recommended: courses 111, and M51A or Electrical and Computer Engineering M116L. Computer system organization and design, implementation of computer control, instruction set design, memory hierarchy (caches, main memory, virtual memory) organization and management, input/output subsystems (bus structures, interrupts, DMA), performance evaluation, pipelined processors. Letter grading. Mr. Reinman, Mr. Tahir (F,Sp)

M152A. Introductory Digital Design Laboratory. (2) (Same as Electrical and Computer Engineering M116L.) Laboratory, four hours; outside study, two hours. Enforced requisite: course M51A or Electrical and Computer Engineering M16. Hands-on design, implementation, and debugging of digital logic circuits. Introduction to schematic capture and simulation, implementation of complex circuits using programmed array logic, design projects. Letter grading. Mr. Potokanik (F)

152B. Digital Design Project Laboratory. (4) Laboratory, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M151B or Electrical Engineering M116C. Recommended: Engineering 183EW or 185EW. Limited to seniors. Design and implementation of complex digital systems using field-programmable gate arrays (e.g., processors, special-purpose processors, device controllers, and input/output interfaces). Students work in teams to design and implement a digital system and give oral presentations of their work. Letter grading. Mr. Sarrafzadeh (F,Sp)

161. Fundamentals of Artificial Intelligence. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 180. Introduction to fundamental problem solving and knowledge representation paradigms of artificial intelligence. Introduction to Lisp with regular programming, logic programming, and problem reduction methods, brute-force and heuristic search, planning techniques, two-player games. Knowledge structures including predicate logic, production systems, semantic nets and primitives, frames, scripts. Special topics include expert systems, knowledge processing, expert systems, vision, and parallel architectures. Letter grading. Mr. Deanech, Mr. Gu, Mr. Van den Broeck (F,Sp)

168. Computational Methods for Medical Imaging. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C with grade of C– or better. Mathematics 32A, one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, or Statistics 100A. Theory and practice of image acquisition, processing, and visualization. Applications of techniques from entertainment (reverse engineering and postprocessing of movies, generation of realistic synthetic objects and characters) to medicine (modeling of biological structures from imaging data and related real-world-based visualization of video), and security (visual surveillance). Fundamental analytical tools for modeling and inferring geometric (shape) and photometric (reflectance, illumination) properties of objects, and for rendering and manipulating novel views. Letter grading. Mr. Soatto (Not offered 2020-21)

C174C. Computer Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. State of art in three-dimensional photography and image-based rendering. How to use cameras and light to capture shape and appearance of real objects and scenes. Process provides simple way to acquire three-dimensional models of unparalleled detail and realism. Applications of technology for entertainment (reverse engineering and postprocessing of movies, generation of realistic synthetic objects and characters) to medicine (modeling of biological structures from imaging data and related real-world-based visualization of video), and security (visual surveillance). Fundamental analytical tools for modeling and inferring geometric (shape) and photometric (reflectance, illumination) properties of objects, and for rendering and manipulating novel views. Letter grading. Mr. Soatto (Not offered 2020-21)

M171L. Data Communication Systems Laboratory. (2) (Same as Electrical Engineering M171L.) Laboratory, four to eight hours; outside study, two to four hours. Recommended prerequisites: course M120A. Limited to seniors. Not open to students with credit in course 171. Introduction to analog signaling and interpretation of analog-signaling aspects of digital systems and data communications through experience in using contemporary test instruments to generate and detect signals in relevant laboratory contexts. Use of oscilloscopes, pulse and function generators, baseband spectrum analyzers, desktop computers, terminals, modems, PCs, and workstations in experiments on pulse transmission impairments, waveforms and their spectra, modem characteristics, and interfaces. Letter grading. (Not offered 2020-21)

172. Real-Time Three-Dimensional Animation. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 32. Introduction to real-time three-dimensional animation by following through from preproduction to postproduction. End products expected to be game demonstrations, storytelling games, or machinima (use of real-time graphics engines to create cinematic productions). Focus on development of quality real-time productions to qualify and submit projects to Student Academy Awards competition. Use of Unity Game Engine to make technical decisions to adapt stories to games. Introduction to current concepts, enabling students to create low-fidelity real-time three-dimensional animation and to concepts in artificial intelligence, enabling them to refine their interactions to create high-fidelity real-time three-dimensional animation. Letter grading. (Not offered 2020-21)

174A. Introduction to Computer Graphics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 32. Basic principles of modern computer graphics systems, including complete set of steps that modern graphics pipelines use to create realistic images in real time. How to position and manipulate objects in scene using geometric and camera transformations. How to create final image using perspective and orthographic transformations. Basics of modeling primitives such as polygonal models and implicit and parametric surfaces. Basic ideas behind color spaces, illumination models, shading, and texture mapping. Letter grading. Mr. Law, Mr. Terzopoulos (F,Sp)

174B. Introduction to Computer Graphics: Three-Dimensional Photography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 174A. State of art in three-dimensional photography and image-based rendering. How to use cameras and light to capture shape and appearance of real objects and scenes. Process provides simple way to acquire three-dimensional models of unparalleled detail and realism. Applications of technology for entertainment (reverse engineering and postprocessing of movies, generation of realistic synthetic objects and characters) to medicine (modeling of biological structures from imaging data and related real-world-based visualization of video), and security (visual surveillance). Fundamental analytical tools for modeling and inferring geometric (shape) and photometric (reflectance, illumination) properties of objects, and for rendering and manipulating novel views. Letter grading. Mr. Soatto (Not offered 2020-21)
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. Mathematical techniques to solve and conquer, greedy method, dynamic programming; selection of prototypical algorithms; choice of data structures and representations; complexity measures, lower bounds, asymptotic notation, NP-completeness. Letter grading.

Mr. Gafni, Mr. Hsieh, Mr. Sarrafzadeh (F,W,S)


Mr. Campbell, Mr. Meka, Mr. Sahai (F,W,S)

M182. Dynamic Biosystem Modeling and Simulation Methodology. (4) (Same as Bioengineering M182.) Lecture, six hours; outside study, four hours. Enforced requisites: Life Sciences 30A and 30B, or Mathematics 3A and 3B, or 31A and 31B. Recommended requisite or corequisite: Mathematics 3C, 32A, or 32T. For undergraduate students in computational, engineering, and mathematical sciences. Active learning approach. Introduction to explicit modeling and simulation of dynamic biological systems. Basic methodology for transforming biology, biochemistry, and mathematical expressions into computer algorithms and simulation models, formulated from basic conservation and developmental biology concepts. Computer models are further transformed into first-order differential equations, and implemented in simulation diagrams for quantifying and exploring biosystem properties. Examples show how to use these explicit models to gain clarity on nature of biosystem phenomena, and frame questions and explore new ideas for research. Letter grading. 

Mr. DiStefano (F)

183. Introduction to Cryptography. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Preparation: knowledge of basic probability theory. Enforced requisite: course 180. Introduction to cryptography, computer security, and basic concepts and methods. Topics include key generation, one-way functions, public-key cryptography, hash functions, digital signatures, zero-knowledge, zero-knowledge proofs, secret sharing, and key management. Letter grading. 

Mr. Ostrovsky (Not offered 2020-21)

M184. Introduction to Computational and Systems Biology. (2) (Same as Bioengineering M184.) Lecture, two hours; outside study, four hours. Enforced requisites: one course from 31, Civil Engineering M20, Mechanical and Aerospace Engineering M20, or Program in Computing 10A; and Life Sciences 30B or Mathematics 3B or 31B. Survey course designed to introduce students to computational and systems biology methodologies for studying data in biology, medicine, providing motivation, flavor, culture, and cutting-edge contributions in computational biosciences and aiming for more informed basis for focused study 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. Eskin (F)

CM186. Computational Systems Biology: Modeling and Analysis of Physical Systems. (4) (Same as Bioengineering CM186, Computational and Systems Biology M186, and Ecology and Evolutionary Biology M178.) Lecture, four hours; laboratory, three hours; outside study, eight hours. Dynamic biosystems modeling and computer simulation methods to be an biological/biomedical processes and systems at multiple levels of organization. Control system, multicompartmental models, pharmacokinetic (PK), pharmacodynamic (PD), and other structural modeling methods applied to life sciences problems at molecular, cellular (biochemical pathways/networks), organ, and organismic levels. Both theoretical and practical aspects, with focus on translating biomodeling goals and data into mathematical models and implementing them for simulation and analysis. Basics of numerical simulation algorithms, with modeling software exercises in Java and/or C. Letter grading. 

Mr. DiStefano (F)

CM187. Research Communication in Computational and Systems Biology. (4) (Same as Bioengineering CM187 and Computational and Systems Biology M187.) Lecture, four hours; outside study, eight hours. Enforced requisite: course M182 or CM186 or Computation and Systems Biology M150. Close-to-real, interactive, and real research experience in active quantitative systems biology research laboratory. Direction on how to focus on topics of current interest in scientific community, to be an institution of 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. Letter grading. 

Mr. DiStefano (Not offered 2020-21)

188. Special Courses in Computer Science. (4) Lecture, four hours; discussion, two hours; outside study, eight hours. Enforced requisite: course M182 or CM186 or Computation and Systems Biology M150. May be repeated for credit. Concurrently scheduled with course CM287. Letter grading. 

192. Methods and Application of Collaborative Learning Theory in Life Sciences. (2) Seminar, two hours; clinic, four hours. Requisites: course 192A or Life Sciences 192 or M213B. Seminar is open to graduate students and interested undergraduate students who are selected for learning assistants (LA) program. Exploration of current topics in pedagogy and education research focused on methods of learning and their practical application in small-group settings. May be repeated for credit. Letter grading. 

192A. Introduction to Collaborative Learning Theory and Practice. (1) Seminar, one hour; outside study, two hours. Training seminar for undergraduate students who are selected for learning assistants (LA) program. Exploration of current topics in pedagogy and education research focused on methods of learning and their practical application in small-group settings. May be repeated for credit. Letter grading.
mended: courses 111, and M151B or Electrical and Computer Engineering 140C. 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, enterprise, and data-center scale. The evaluation of putting, networking, sensing, and control technologies and algorithms for improving energy sustainability in human-cyber-physical systems. Topics include energy consumption, energy modeling and management; low-power protocols; battery modeling and management; and self-awareness, sensing of power consumption. Letter grading.

Mr. Srivastava (Not offered 2020-21)

216. Network Algorithms. (4) Lecture, four hours; outside study, eight hours. Recommended preparation: one course on networks. Requisite: course 211. Introduction to algorithms for routers and servers. Models of network devices and hardware design. Principles for efficient implementation. Lookup algorithms (exact match, prefix lookups, advanced cache life support), fair queueing implementations, crossbar and scalable switches, with examples from well-known networking devices. Advanced topics include traffic measurement and network security. Students report on selected topics. Letter grading.

Mr. Varghese (Sp)

217A. Internet Architecture and Protocols. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 111. Focus on mastering existing core set of Internet protocols, including IP, core 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 2020-21)

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

218. Advanced Computer Networks. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 32 or Program in Computing 10C with grade of C- or better, Mathematics 33A, and one course from Civil Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A. Course CM221 is not requisite to CM222. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Computational techniques include models of statis- ics and computer science. Concurrently scheduled with course CM122. Letter grading.

Mr. Eskin (Sp)

CM222. Machine Learning Applications in Genet- ics. (4) (Same as Bioinformatics M224 and Human Genetics CM224) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: course 32 or Program in Computing 10C with grade of C- or better, Mathematics 33A, and one course from Civil Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, or Statistics 100A. Designed for engineering students as well as students from biological sciences and medical school. Development and application of computational approaches to biological questions, with focus on formulating interdisciplinary problems as computational problems and then solving these problems using algorithmic techniques. Topics include statistics and computer science. Concurrently scheduled with course CM122. Letter grading.

Mr. Eskin (Sp)

CM224. Machine Learning Applications in Genet- ics. (4) (Same as Bioinformatics M224 and Human Genetics CM224) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for graduate engineering students as well as students from biological sciences and medical school. Introduction to current topics in machine learning, genomics, and computer science. Students report on selected topics. Letter grading.

Mr. Srivastava (Not offered 2020-21)

219. Current Topics in Computer System Model- ing Analysis. (4) Lecture, four hours; outside study, four hours. Review of current literature in area of computer system modeling analysis in which instructor has developed special proficiency as consequence of research interests. Students report on selected topics. May be repeated for credit with consent of instructor. Letter grading.

Mr. Varghese (W)

CM221. Introduction to Bioinformatics. (4) (Same as Biochemistry M221 and Human Genetics M260A) Lecture, four hours; discussion, two hours. Requisites: 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 interested in biological sciences and medical school. Introduction to bioinformatics and methodologies, with emphasis on concepts and inventing new computational and statistical techni- ques to analyze biological data. Focus on sequence analysis techniques and statistical algorithms. Currently scheduled with course CM121. S/U or letter grading.

Mr. Sul (F)

230. Software Engineering. (4) Lecture, four hours; discussion, two hours. Recommended preparation for undergraduate students: prior software engi- neering course. Required preparation for graduate students: undergraduate-level knowledge of data structures and object-oriented program languages. As software systems become increasingly large and complex, automated software engineering analysis and development tools play important role in various software engineering tasks, such as design, construction, evolution, and testing and debugging of software systems. Introduction to foundations, tech- niques, tools, and applications of automated soft- ware engineering technology. Development, exten- sion, and evaluation of mini automated software en- gineering analysis tool and assessment of how tool fits into software development process. Introduction to database technology. Letter grading.

Ms. Kim (Sp)

231. Types and Programming Languages. (4) Lecture, four hours; outside study, eight hours. Requisite: course 131. Introduction to static type systems and their use in program design and software reliability. Operational semantics, simply- typed lambda calculus, type soundness proofs, types for mutable references, types for exceptions. Para- metric polymorphism, higher-order, generic and polymorphic type inference. Types for objects, subtyping, combining parametric polymorphism and subtyping. Types for modules, parameterized modules. Formal specification and implementation of type systems, as well as readings from recent research liter- ature on modern applications of type systems. Letter grading.

Mr. Millstein (W)


Mr. Palash (Not offered 2020-21)

233A. Parallel Programming. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 131. Mutual exclusion and resource allocation in distributed systems; primitives for parallel computa- tion; specification of parallelism; interprocess commu- nication and synchronization, atomic actions, bi- nary and multway rendezvous; synchronous and asynchronous languages; CSP, Ada, Linda, Maude, and others; introduction to parallel program verifi- cation. Letter grading.

Mr. Cong (Not offered 2020-21)

233B. Verification of Concurrent Programs. (4) Lecture, four hours; outside study, eight hours. Requ- isite: course 233A. Font verification of concurrent programs. Topics include safety, liveness, program and state assertion-based tech- niques, weakest precondition semantics, Hoare logic, temporal logic, UNITY, and model checking for selected parallel languages. Letter grading.

Mr. Bagrodia (Not offered 2020-21)
234. Computer-Aided Verification. (4) Lecture, four hours; outside study, eight hours. Requisite: course M181. Introduction to theory and practice of formal methods for design and analysis of concurrent and embedded systems, with focus on algorithmic techniques for the verification of program properties and software systems. Topics include semantics of reactive systems, invariant verification, temporal logic model checking, theory of omega automata, state-space reduction techniques, compositional and hierarchical reasoning. Letter grading. Mr. Majumdar (Not offered 2020-21)

235. Advanced Operating Systems. (4) Lecture, four hours. Preparation: C or C++. programming experience. Offered alternate years starting Fall 2011. In-depth investigation of operating systems issues through guided construction of a research operating system for PC machines and consideration of recent literature. Memory management, interprocess communication, preemptive multitasking, file systems, Virtualization, networking, profiling, research operating systems. Series of laboratory projects, including extra credit projects. Letter grading. Mr. Egert (Not offered 2020-21)

236. Computer Security. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 111, 118. Basic and research material on computer security. Topics include access control, management of public and private keys, cryptology, common security tools, use of cryptographic protocols for security, security tools (firewalls, virtual private networks, honeypots), virus and worm protection, security assurance and testing, design of secure programs, privacy, applying security principles to real problems, and new and emerging threats and security tools. Letter grading. Mr. Palasberg, Mr. Reiter (Not offered 2020-21)

C237A. Prototyping Programming Languages. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced prerequisite: course 131. How different programming language paradigms provide dramatically different way 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 prototyping implementations of languages in each. Analysis of prototypes to shed light on design and structural properties of each language and paradigm and to allow easy comparison against one another. Exploration on implementation by implementing new abstractions, both as stand-alone languages and as libraries in existing languages. Concurrently scheduled with course C137A. Letter grading. Mr. Milstein

C237B. Programming Language Design. (4) Seminar, four hours; outside study, eight hours. Enforced prerequisite: course C237A. Study of various programming language designs, from computing history and research literature, that 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 C137B. 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 computer science programming languages and systems in which instructor has developed special proficiency as consequence of research interests. May be repeated for credit with consent of instructor. Letter grading. Mr. Milstein

240A. Data bases and Data Mining Bases. (4) Lecture, four hours; outside study, eight hours. Requisite: course 143. Theoretical and technological foundation of Intelligent Database Systems, that merge database technology, knowledge-based systems, and advanced programming environments. Rule-based knowledge representation, spatio-temporal reasoning, and logic-based declarative querying/pro- gramming are salient features of this technology.

240B. Advanced Data and Knowledge Bases. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 143, 240A. Logical models for data and knowledge representation, object-oriented languages and nonmonotonic reasoning. Temporal que- ries, spatial queries, and uncertainty in deductive da- tabases and object relational databases (ORDBs). Abstracts for data between user-defined functions. Data- bases, ORDBs, data mining algorithms. Semistructured information. Letter grading. Mr. Parker, Mr. Zaniolo (Not offered 2020-21)

241B. Pictorial and Multimedia Database Manage- ment. (4) Lecture, four hours; discussion, three minutes; laboratory, one hour; outside study, seven hours. Requisite: course 143. Multimedia data: alphanumeric, text images, pictures, video, and voice. Multimedia information systems requirements. Data models. Searching and accessing databases and across Internet by alphanumeric, image, video, and audio content. Querying, visual languages, and communication. Database design and organization. Logical and physical. Indexing methods. Internet multi- media streaming. Other topics at discretion of instruc- tor. Letter grading. (Not offered 2020-21)

244A. Distributed Database Systems. (4) Lecture, four hours; outside study, eight hours. Requisite: course 244B. Advanced topics in distributed computing, intelligent directory design, transaction management, deadlock, strong and weak concurrency control, commit protocols, semantic query answering, multi- database systems, fault recovery techniques, net- work partitioning, examples, trade-offs, and design experiences. Letter grading. (Not offered 2020-21)

245. Big Data Analytics. (4) Lecture, four hours; out- side study, eight hours. Requisites: courses 143 or 180 or equivalent. With unprecedented speed 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 exercises in applying analytics. Topics include bioin- formatics, E-commerce, environmental study, finan- cial market study, multimedia data processing, net- work monitoring, social media analysis. Letter grading. Mr. Wang (F)

246. Web Information Management. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 112, 143, 180, 181. Designed for graduate students. Scale of Web data requires novel algo- rithms and principles for their management and re- trieval. Study of Web characteristics and new man- agement techniques needed to build computer sys- tems suitable for Web environment. Topics include Web measuring techniques, large-scale data mining algorithms, efficiency, effectiveness, techniques, web- search ranking algorithms, and query processing techniques on independent data sources. Letter grading. Mr. Cho (Sp)

247. Advanced Data Mining. (4) Lecture, four hours; outside study, eight hours. Requisite: course 145 or M146 or equivalent. Introduction of concepts, algo- rithms, and techniques of data mining on different types of datasets, covering basic data mining algo- rithms and advanced techniques. Review of recom- mender systems, and graph/network mining. Team- based project involving hands-on practice of mining useful knowledge from large data sets is required. Letter grading. Mr. Cho (Sp) (Not offered 2020-21)

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

251A. Advanced Computer Architecture. (4) Lecture, four hours; outside study, eight hours. Requisite: course M151B. Recommended: course 111. Design and implementation of modern computer architectures, advanced memory hierarchy techniques, static and dynamic pipelining, superscalar and VLIW proces- sors, branch prediction, speculative execution, soft- ware support for instruction-level parallelism, simula- tion-based performance analysis and evaluation, state-of-art design examples, introduction to parallel architectures. Letter grading. Mr. Tamir (F), Mr. Nowatzki (W)


M252A. 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, two hours. Requisite: course M51A or Electrical and Com- puter Engineering M16, and Electrical and Computer Engi- neering 115A. Recommended: Electrical and Computer Engineering 115C. VLSI/LSI design and application in computer systems. Fundamental de- sign techniques that can be used to implement com- plex integrated systems on chips. Letter grading.

M252C. LSI in Computer System Design. (4) (Same as Electrical and Computer Engineering M216C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M252A. LSI/VLSI design and application in computer sys- tems. In-depth studies of VLSI architectures and VLSI design. Letter grading.

258F. Physical Design Automation of VLSI Sys- tems. (4) Lecture, four hours; outside study, eight hours. Detailed study of various physical design au- tomation problems of VLSI circuits, including logic partitioning, floorplanning, placement, global routing, channel and switchbox routing, planar routing and via minimization, compaction and performance-driven layout. Discussion of applications of number of im- portant minimization techniques, such as cell migration, Steiner trees, simulated annealing, and genetic algorithms. Letter grading. Mr. Cong

258G. Logic Synthesis of Digital Systems. (4) Lecture, four hours; outside study, eight hours. Requi- sites: courses M51A, 180. Detailed study of various problems in logic synthesis of VLSI digital sys-
Current Topics in Computer Science: System Design/Architecture. (2 to 12) Lecture, four hours; outside study, eight hours. Review of current literature in area of computer science system design in which instructor has developed special proficiency as consequences from theory. Identifying causal effects. Covariate selection and instrumental variables. Synchronization of visual and other sensory information. Unified treatment of advanced computer system and machine. Integration of symbolic and iconic representations in process of image segmentation. Computing multimodal sensory information by neural-net architectures. Letter grading. (Not offered 2020-21)


M267A. 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 Markov logic networks, as well as various probabilistic programming languages. Covers their syntax and semantics, probabilistic inference problems, parameter and structure learning, and theoretical properties of representation and inference. Expressive statistical modeling, how to formalize and reason about complex statistical assumptions and encode knowledge in machine learning models. Survey of key applications of probabilistic programming: machine learning, graph mining, computer vision, and computational biology. Letter grading. (Not offered 2020-21)

that are used in computer vision, image processing, speech recognition, data mining, statistics, and com-
nutational biology. Topics include Bayesian decision
theory, parametric and nonparametric learning, clus-
tering, complexity (VC-dimension, MDL, AIC), PCA/
ICA/TCA, MDS, SVM, boosting, SIU or letter grading.
Mr. Zhu (Not offered 2020-21)

280A-280ZZ. Algorithms. (4 each) Lecture, four
hours; outside study, eight hours. Requisite: course 180.
Additional requisites for each offering announced by department. Selections from design,
analysis, optimization, and implementation of algorithms;
computational complexity and general theory of algorithms; algorithms for particular applica-
tion areas and current trends. Prerequisites: Funda-
ciples of Design and Analysis (280A); Distributed Al-
gorithms (280D); 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.
Theoretically sound techniques for dealing with NP-
Hard problems. Methods to turn a theoretically non-
efficiently means algorithmic techniques are based on
approximation—finding solution that is near to best
possible in efficient running time. Coverage of ap-
proximation algorithms. Emphasis on different difficult
problems, with algorithm design techniques that include
primal-dual method, linear program rounding, greedy
algorithms, and local search. Letter grading.

(Not offered 2020-21)

281A. Computability and Complexity. (4) Lecture,
four hours; outside study, eight hours. Requisite:
course 181 or compatible background. Concepts
fundamental to study of discrete information systems
and theory of the abstract efficient problem solving.
Topics include notions of hardness, one-way func-
tions, hard-core bits, pseudorandom generators,
pseudorandom functions and pseudorandom permu-
tations, zero-knowledge proofs, encryption, secret-
sharing, message authentication, digital signatures,
interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commit-
tment protocols, key-agreement, contract signing,
and two-party secure computation with static secu-
re. Letter grading.
Mr. Sherstov (F)

M282A. Cryptography. (4) (Same as Mathematics
M209A.) Lecture, four hours; outside study, eight
hours. Introduction to theory of cryptography,
stressing rigorous definitions and proofs of security.
Topics include notions of hardness, one-way func-
tions, hard-core bits, pseudorandom generators,
pseudorandom functions and pseudorandom permu-
tations, zero-knowledge proofs, encryption, secret-
sharing, message authentication, digital signatures,
interactive proofs, zero-knowledge proofs, collision-resistant hash functions, commit-
tment protocols, key-agreement, contract signing,
and two-party secure computation with static secu-
re. Letter grading.
Mr. Ostrovsky (Not offered 2020-21)

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; con-
current non-black box zero-knowledge; IP=PSPACE
proof, stronger notions of security for public-key encryption, including chosen-ciphertext
security; secure multiparty computation; dealing with dynamic adversary; nonmallevable and compos-
ability of secure protocols; software protection;
threshold cryptography; identity-based cryptog-
raphy; private information retrieval; protection against man-in-the-middle attacks; voting protocols; identifica-
tion protocols; digital cash schemes; lower bounds
on use of cryptographic primitives, software obfusc-
uation. May be repeated for credit with topic change.
Letter grading. (Not offered 2020-21)

M283A-M283B. Topics in Applied Number Theory.
(4--4) (Same as Mathematics M208A-M208B.) Lect-
ture, three hours. Basic number theory, including
congruences and prime numbers. Cryptography:
public-key and RSA cryptosystems. Attack on
cryptosystems. Primality testing and factorization
methods. Elliptic curve methods. Topics from coding
theory; Hamming codes, cyclic codes, Gilbert/Var-
shamov/Gilbo bounds, Shannon theorem. Lecture or
letter grading. (Not offered 2020-21)

284A-284ZZ. Topics in Automata and Languages.
(4 each) Lecture, four hours; outside study, eight
hours. Requisite: course 181. Additional requisites for
each offering announced by department. Selections from families of formal languages, gram-
mars, machines, operators; pushdown automata,
context-free languages and their generalizations,
parsing; multidimensional grammars and development
of systems; machine-based complexity. Subtles of
some current and planned sections: Context-Free
Languages (284A), Parsing Algorithms (284P). May
be repeated for credit with consent of instructor and
topic change. Letter grading.
Mr. Sahai (Sp)

CM286. Computational Systems Biology: Model-
ing and Simulation of Biological Systems. (5)
(Same as Bioengineering CM286.) Lecture, four
hours; laboratories, three hours; outside study, eight
hours. Dynamic biosystems modeling and computer
simulation methods for studying biological/biomed-
ical processes and systems at multiple levels of organi-
sation. Introduction to system level modeling of differ-
cent and organismic levels. Both theory- and data-driven modeling, with focus on translating biomodeling goals and data into
mathematics models and implementing them for sim-
ulation and analysis. Basics of numerical simulation
algorithms, with modeling software exercises in class
and PC laboratory assignments. Concurrently sched-
uled with course CM186. Letter grading.
Mr. DiStefano (Sp)

CM287. Research Communication in Compu-
tational and Systems Biology. (4) (Same as Bioengi-
neering CM287.) Lecture, four hours; outside study,
eight hours. Requisite: course M182 or CM286 or
Computing and Information Science M150. Closely
directed, interactive, and real research experience in
active quantitative systems biology research labora-
tory. Direction on how to focus on topics of current
interest in scientific community, appropriate to stu-
dent interests and capabilities. Critiques of oral pre-
sentations and written progress reports explain how to
proceed with search for research results. Major
emphasis on effective research reporting, both oral and
written. Work closely scheduled with course CM187.
Letter grading.

Mr. DiStefano (Not offered 2020-21)

288S. Seminar: Theoretical Computer Science. (2-
5) Seminar, two hours; outside study, six hours. Requir-
te: consent of instructor. An upper division course for
students undertaking thesis research. Discussion of advanced topics and current research in such areas as algo-
rithms and complexity models for parallel and con-
current computation, and formal language and au-
tomata theory. May be repeated for credit. SU grading.
(Not offered 2020-21)

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 inter-
est. Students report on selected topics. Letter grading.

289CC. Complexity Theory. (4) Lecture, four hours;
outside study, eight hours. Diagonalization, poly-
nomial-time hierarchy, PCP theorem, randomness and
decomposition, circuit complexity, attempts and
limitations to provide lower bounds for average-
case complexity, one-way functions, hardness ampli-
ification, Problem sets and presentation of previous
and original research related to course topics. Letter
grading. (Not offered 2020-21)

289OA. Online Algorithms. (4) Lecture, four hours;
outside study, eight hours. Requisite: course 180. In-
roduction to decision making under uncertainty and
competitive analysis. Review of current research in
online algorithms for problems arising in many areas,
such as data and memory management, searching
and navigation, computation in unknown topology for
network systems. Letter grading. (Not offered 2020-21)

289RA. Randomized Algorithms. (4) Lecture, four
hours; outside study, eight hours. Basic concepts and
design techniques for randomized algorithms,
such as probably correct, Markov chains, random
walks, and probabilistic method. Applications to ran-
domized algorithms in data structures, graph theory,
computational geometry, number theory, and parallel
and distributed systems. Letter grading.

(Not offered 2020-21)

M296A. Advanced Modeling Methodology for Dy-
namic Biomedical Systems. (4) (Same as Bioengi-
neering M296A and Medicine M270C.) Lecture, four
hours; outside study, eight hours. Basic concepts and
design techniques for modeling dynamic systems
materials, such as probability theory, Markov chains,
random walk, and probabilistic method. Applications to
randomized algorithms in data structures, graph theory,
computational geometry, number theory, and parallel
and distributed systems. Letter grading.

(Not offered 2020-21)

M296B. Optimal Parameter Estimation and Exper-
iment Design for Biomedical Systems. (4)
(Same as Bioengineering M296B, Biomathematics M270,
and Medicine M270D.) Lecture, four hours; outside study,
eight hours. Requisite: course CM286 or M289A or Bi-
omathematics 220. Estimation methodology and model
parameter estimation algorithms for fitting dynamic system models to biomedical data.
Model discrimination methods. Theory and algo-
rithms for designing optimal experiments for devel-
oping 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 physi-
ology and pharmacology.

Mr. DiStefano (Not offered 2020-21)

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 M296B. Research tech-
niques and experience on special topics involving
methods or modeling methodology justifying in bio-
logical and medical sciences. Review and critique of
literature. Research problem searching and formu-
lation. Approaches to solutions. Individual MS- and
PhD-level project training. Letter grading.

Mr. DiStefano (Not offered 2020-21)

M296D. Introduction to Computational Cardi-
ology. (4) (Same as Bioengineering M296D.) Lecture,
four hours; outside study, eight hours. Requisite:
course CM186. Introduction to mathematical mod-
eling and computer simulation of cardiac electro-
physiological process. Ionic models of action poten-
tial (AP). Theory of AP propagation in one-dimen-
sional and two-dimensional cardiac tissue. Simulation on sequential and parallel supercom-
puters, choice of numerical algorithms, to optimize
accuracy and to provide computational stability.
Letter grading.

Mr. DiStefano (Not offered 2020-21)

298S. Research Seminar: Computer Science. (2 to
4) Seminar, two to four hours; outside study, four
to eight hours. Designed for graduate computer science
students. Discussion of advanced topics and current
research in algorithmic processes that describe and
compute. Emphasis on algorithms that are efficient, ef-
ciency, implementation, and application. May be re-
pealed for credit. SU grading.

375. Teaching Apprentice Practicum. (1 to 4) Sem-
inars, to be arranged, in cooperation with per-
sonnel employed as teaching assistant, associate,

or fellow. Teaching apprentice under active guid-
ance and supervision of regular faculty member re-
sponsible for curriculum and instruction at UCLA.
May be repeated for credit. SU grading.

(F,W,Spring)
Electrical and Computer Engineering

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Professors
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Abeer A.H. Alwan, Ph.D.
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Robert N. Candler, Ph.D.
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Stefano Soatto, Ph.D.
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Mani B. Srivastava, Ph.D.
Paulo Tabuada, Ph.D. (Vijay K. Dhir Professor of Engineering)
Lieven Vandenberghe, Ph.D.
Mihaela van der Schaar, Ph.D. (Chancellor’s Professor)
John D. Villasenor, Ph.D.
Kang L. Wang, Ph.D. (Raytheon Company Professor of Electrical Engineering)

Yuanxun Ethan Wang, Ph.D.
Richard D. Wesel, Ph.D., Associate Dean
Benjamin S. Williams, Ph.D.
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C.-K. Ken Yang, Ph.D.

Professors Emeriti
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Babak Daneshdar, Ph.D.
Harold R. Fetterman, Ph.D.
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Rajeev Jain, Ph.D.
William J. Kaiser, Ph.D.
Alan J. Laub, Ph.D.
Nhan N. Levan, Ph.D.
Dee-Son Pan, Ph.D.
Izhak Rubin, Ph.D.
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Achuta Kadambi, Ph.D.
Jonathan C. Kao, Ph.D.
Ankur Mehta, Ph.D.
Nader Sehatbakhsh, Ph.D.
Lin F. Yang, Ph.D.

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Dan M. Goebel, Ph.D.
Diana L. Huffaker, Ph.D.
Asad M. Madni, Ph.D.
Ingrid M. Verbauwhede, Ph.D.
Eli Yablonovitch, Ph.D.

Adjunct Associate Professor
Chi On Chui, Ph.D.

Adjunct Assistant Professors
Shervin Moloudi, Ph.D.
Zachary Taylor, 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 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 telecommunications, 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 and Computer 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 industrial and government agencies, (4) achieve visibility by active participation in conferences and technical and community activities, and (5) publish enduring scientific articles and books.

**Electrical Engineering Undergraduate Program Educational Objectives**

The electrical engineering program is accredited by the Engineering Accreditation Commission of ABET. 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, 122A, 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—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 22 or the GE Requirement web page.

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, 141, 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.

Electrostatics and Optimization: The study of control 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 112, 133A, 133B, 141, 142 and 8 capstone design units from 180DA/180DB or 183DA/183DB.

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 112, 133A, 133B, 141, 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, 115C, M116C, M116L, M119, and 142 and 8 capstone design units from 180DA/180DB 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.

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.

Simulation and Data Analysis: Studies focus on applications related to the processing of big data for both analog/multimedia and digital sources. Students might take 12 units selected from Electrical and Computer Engineering 114, 132A, 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, C102, 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 from electives from Electrical and Computer Engineering 115C, M116C, M116L, M119, 123B, 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, M132B, 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, robotics 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 M6); 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 M16C), M152A (or Electrical and Computer Engineering M16L), 180; Electrical and Computer Engineering 100, 102, 113, 115C; one course from Civil and Environmental Engineering 110, Electrical and Computer Engineering 131A, Mathematics 170A, 170E, 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 22 or the GE Requirement web page.

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.

**Students**

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 26.

The following introductory information is based on 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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 and Computer Engineering.

**Electrical and Computer Engineering M.S.**

**Areas of Study**

Students may pursue specialization across three major areas of study: (1) circuits and embedded systems, (2) physical and wave electronics, and (3) signals and systems. These areas cover a broad spectrum of specializations in, for example, communications and telecommunications, control
systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics. Students must select a number of formal graduate courses to serve as their major and minor fields of study according to the requirements listed below for the thesis (seven courses) and non-thesis (eight courses) options. The selected courses must be approved by the faculty adviser.

Course Requirements

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, and (e) no other 500-level courses, other seminar courses, or Electrical and Computer Engineering 296 or 375 may be applied toward the course requirements
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 re-examined 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 co-design; 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
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 system, 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, 208A, 208C, 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 or (2) through completion of an individual study course (Electrical and Computer Engineering 299) under the direction of a faculty member. Students are assigned a topic of individual study by the faculty member. The study culminates with a written report and an oral presentation. The M.S. individual study program is administered by the faculty member directing the course, the director of the area to which the students belong, and the vice chair of Graduate Affairs. Students who fail the examination may be reexamined only once with consent of the vice chair of Graduate Affairs.

**Electrical and Computer 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 courses taken to meet the M.S. degree requirements may not be applied toward the Ph.D. course requirements
6. At least two of the formal graduate courses must be in electrical and computer engineering
7. Within two academic years from admission into the Ph.D. program, all courses should be completed and the Ph.D. preliminary examination should be passed. It is strongly recommended that students take the Ph.D. preliminary examination during their first academic year in the program
8. The University Oral Qualifying Examination must be taken when all required courses are complete, and within one year after passing the Ph.D. preliminary examination
9. Students admitted originally to the M.S. program in the Electrical 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
10. Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus

**Written and Oral Qualifying Examinations**

The written qualifying examination is known as the Ph.D. preliminary examination in the department. The purpose of the examination is to assess student competency in the discipline, knowledge of the fundamentals, and potential for indepen-
dent 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, which is held once every year. Students are examined independently by a group of faculty members in their general area of study. The examination by each faculty member typically includes both oral and written components, and students pass the entire Ph.D. preliminary examination and not in parts. Students who fail the examination may repeat it once only with consent of the departmental graduate adviser. The preliminary examination, together with the course requirements for the Ph.D. program, should be completed within two years from admission into the program.

After passing the written qualifying examination described above, students are ready to take the University Oral Qualifying Examination. The nature and content of the examination are at the discretion of the doctoral committee, but ordinarily include a broad inquiry into the preparation for research. The doctoral committee also reviews the prospectus of the dissertation at the oral qualifying examination.

Students must nominate a doctoral committee prior to taking the University Oral Qualifying Examination. A doctoral committee consists of a minimum of four members. Three members, including the chair, are inside members and must hold appointments in the department. The outside member must be a UCLA faculty member in another department. By petition, one of the four members may be a faculty member from another UC campus.

Facilities and Programs

Computing Resources

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)

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 (CEELN)

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 Center for Heterogeneous Integration and Performance Scaling addresses emerging technologies, design, and architectures to achieve a more holistic Moore’s Law for the overall system. It has pioneered the chiplet/dielet approach to heterogeneous integration on both rigid and flexible platforms, and the logic-based charge trap transistor for in-memory analog computation. Core activities include advanced heterogeneous hardware integration technologies, methodologies, and tools; wafer-scale integration; active and passive components for advanced systems; and in-memory analog computing. CHIPS applies these methods to the development of large-scale reliable systems.

CHIPS is multidisciplinary, integrating specialties and students in diverse areas that include electrical and computer engineering, computer science, materials science and engineering, mechanical engineering, computer science and engineering, biosciences, and medicine; with strong industry participation. CHIPS is unabashedly hardware focused, and develops students who want to build and test what they design, much of it in-house.

Center for High-Frequency Electronics

The Center for High-Frequency Electronics was established with support from several government 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 solid-state millimeter wave devices, millimeter systems for imaging and communications, millimeter wave high-power sources (gyrotrons), GaAs gigabit logic systems, and VLSI and LSI based on new materials and structures. The center supports work in these areas by supplying the necessary advanced equipment and facilities and allows the University to play a major role in initiating and generating investigations into new electronic devices. Students, both graduate and undergraduate, receive training and instruction in a unique facility.

The second major goal of the center is to bring together the manpower and skills necessary to synthesize new areas of activity by stimulating interactions between different interdependent fields. The Electrical and Computer Engineering Department, other departments within UCLA, and local universities (such as Caltech and USC) have begun to combine and correlate certain research programs as a result of the formation of the center.

Clean Energy Research Center–Los Angeles (CERC–LA)

Lei He, Director

CERC–LA was created by UCLA to tackle many of the grand challenges related to generation, transmission, storage, and management of energy. As many energy challenges are global in nature, this center engages the participation of a multidisciplinary group of researchers from many nations. CERC–LA leads a U.S.-China clean energy and climate change research consortium. CERC–LA, together with the China National Center for Climate Change Strategy and International Cooperation (NCSC), Peking University (PKU), and Fudan University, was selected by the U.S. Department of State and the China Na-
tional Development and Reform Commission as a U.S.-China EcoPartner. CERC–LA plans to have satellite offices in other cities including Shanghai and Beijing.

Circuits Laboratories
The 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 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 antennas, numerical visualization of electromagnetic waves, electromagnetic scattering and radar cross-section measurements, and antenna near field and diagnostics measurements.

Koç UCLA Translational Research Center
Aydogan Ozcan, Director

The center is a world-leading research nexus for new imaging, sensing, and diagnostics technologies to use in creating a massively scalable suite of ubiquitous computational laboratories, which will significantly improve the tool set for probing micro- and nano-scale objects and processes. Its focus on simplified and cost-effective designs for these analysis tools ensures they are especially suitable for point-of-care and home use, and for professional needs in resource-constrained settings. Through these next-generation technologies, the laboratory will create integrated self-learning systems and networks, specifically for sensing and diagnosis, that aim to impact measurement challenges in application focus areas—such as point-of-care medicine, mobile health, telemedicine, and environmental monitoring—with highly sensitive, specific, and yet remarkably cost-effective and massively scalable technological solutions.

Nanoelectronics Research Facility (Nanolab)

Nanolab is a state-of-the-art, 20,000-square-foot, class 10/1001000 clean-room facility that supports graduate research and teaching. The space includes the Microlab, an undergraduate teaching laboratory for device fabrication (CMOS, MEMS, and optoelectronics). With a full complement of utilities (high-purity deionized water, high-purity nitrogen, exhaust scrubbers) and the latest technologies in vibration isolation and electromagnetic shielding, Nanolab offers advanced processing equipment for fabrication and analysis. In BSL2-capable biosuites, researchers can leverage standard semiconductor process techniques with evolving biomedical, nanometer-scale fabrication to study fundamental quantum size effects; and explore novel nanometer-scale device concepts. Nanolab staff has deep knowledge of fabrication techniques and process development to support both academic and commercial research and development projects.

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 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 spectrograph and multichannel analyzer. Parametric instabilities such as stimulated Raman scattering have been studied, as well as the resonant excitation of plasma waves by optical mixing. The second laboratory, located in Boelter Hall, houses the MARS laser, currently the largest on-campus university CO2 laser in the U.S. It can produce 200J, 170ps pulses of CO2, radiation, focussable to 1016 W/cm2. The laser is used for testing new ideas for laser-driven particle accelerators and free-electron lasers. Several high-pressure, short-pulse drivers can be used on the MARS. Other equipment includes a theta-pinched plasma generator, an electron linac injector, and electron detectors and analyzers.

A second group of laboratories is dedicated to basic research in plasma sources for basic experiments, plasma processing, and plasma heating.

There is also a large computing cluster called DAWSON 2 that is dedicated to the study of plasma-based acceleration, inertial fusion energy, and high-energy-density plasma science. DAWSON 2 consists of 96 HP L390 nodes, each with 12 Intel X5650 CPUs and 48 GB of RAM; and three Nvidia M2070s GPUs and 18 GB of global memory (for a total of 1152 CPUs and 288 GPUs) connected by a nonblocking 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 in 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 mask-making 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 facili-
ties 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 leads 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 offer training in end-to-end product development and delivery for WHI program managers.

WHI develops innovative, wearable biomedicine 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)
- WIN 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)
- CAD for VLSI Design and Manufacturing, Machine Learning Systems in Emerging Technologies (Gupta)
- 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 (I2BL) (Emaminejad)
- Laboratory for Embedded Machines and Ubiquitous Robotics (Mehta)
- Laser-Plasma Group (Joshi)
- MedAdvance: Machine Learning and Artificial Intelligence for Medicine (van der Schaft)
- Mesoscopic Optics and Quantum Electronics Laboratory (Wong)
- Microwave Electronics Laboratory (Itoh)
- Nanoelectronics Research Center (Candler)
- Nanostructure Devices and Technology Laboratory (Chui)
- Networked and Embedded Systems Laboratory (Srivastava)
- Neural Computation and Engineering Laboratory (Kao)
- Neuroengineering Group (Markovic)
- Open Processor Laboratory (He)
- Optoelectronics Circuits and Systems Laboratory (Jalali)
- Optoelectronics Group (Yablonovitch)
- Public Safety Network Systems Laboratory (Yao, Rubin)
- Quantum Biology Tech (QuBiT) (Aiello)
- Quantum Electronics Laboratory (Stafudd)
- Robust Information Systems Laboratory (Dolecek)
- Secure Systems and Architectures (SSysArch) (Sehatbakhsh)
- 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
Abeer A.H. Alwan, Ph.D. (MIT, 1992) Speech processing, acoustic properties of speech sounds with applications to speech synthesis, recognition by machine and coding, hearing-aid design, and digital signal processing
Katsushi Arisaka, Ph.D. (U. Tokyo, Japan, 1985) High energy and astroparticle experiments
Darijela Cabric, Ph.D. (UC Berkeley, 2007) Wireless communications system design, cognitive radio networks, VLSI architectures of signal processing and digital communication algorithms, performance analysis and evaluations, on-chip-embedded system platforms
Robert N. Candler, Ph.D. (Stanford, 2006) MEMS/NEEMS for compact free-electron lasers, miniature medical devices, nanoscale magnetic structures and devices, additive manufacturing, fundamentals of limits of micro- and nano-scale devices
M.-C. Frank Chang, Ph.D. (National Chiao-Tung U., Taiwan, 1979) High-speed semiconductor (GaAs, InP, Si) devices and integrated circuits for digital, analog, microwave, and optoelectronic integrated circuit applications
Panagiotis D. Christofides, Ph.D. (U. Minnesota, 1996) Process modeling, dynamics and control, computational and applied mathematics
Jason (Jingsheng) Cong, Ph.D. (U. Illinois, 1990) Computer-aided design of VLSI circuits, fault-tolerant design of VLSI systems, design and analysis of algorithms, computer architecture, reconfigurable computing, design for nanotechnologies
Suhas Diggavi, Ph.D. (Stanford, 1999) Wireless communication, information theory, wireless networks, data compression, signal processing
Lara Dolecek, Ph.D. (UC Berkeley, 2007) Information and coding theory, graphical models, statistical algorithms and computational methods with applications to large-scale and complex systems for data processing, communication and storage
Christina Fragouli, Ph.D. (UCLA, 2000) Network coding, algorithms for networking, wireless networks and network security
Puneet Gupta, Ph.D. (UC San Diego, 2007) CAD for VLSI design and manufacturing, physical design, manufacturing-aware circuits and layouts, design-aware manufacturing
Lei He, Ph.D. (UCLA, 1999) Artificial intelligence (AI) and Internet of things (IoT) for education, health, transportation, and power and water sustainability; programmable logic (FPGA), reconfigurable computing, AI-on-a-chip, neuromorphic computing, and quantum computing; modeling, simulation, design, and computer-aided design of VLSI circuits, software, and IoT systems.
Tatsuo Itoh, Ph.D. (U. Illinois Urbana, 1969) Microwave and millimeter wave electronics; guided wave structures; low-power wireless electronics; integrated passive components and antennas; photonic bandgap structures and meta materials applications; active integrated antennas, smart antennas; RF technologies for reconfigurable front-ends; sensors and transponders
Subramanian S. Iyer, Ph.D. (UCLA, 1981) Heterogeneous system integration and scaling, advanced packaging and 3D integration, technologies and techniques for memory sub-system integration and neuromorphic computing
Bahram Jalali, Ph.D. (Columbia, 1989) RF photonicics, integrated optics, fiber optic integrated circuits
Mona Jarrahi, Ph.D. (Stanford, 2007) Radio frequency (RF), microwave, millimeter-wave, and terahertz circuits, high-frequency devices and circuits, integrated photonics and optoelectronics
Kuo-Nan Liou, Ph.D. (New York U., 1971) Radiative transfer, remote sensing of clouds and aerosols and climate/clouds-aerosols research
Jia-Ming Liu, Ph.D. (Harvard, 1982) Nonlinear optics, ultrafast optics, laser chaos, semiconductor lasers, optoelectronics, photonics, nonlinear and ultrafast processes
Dejan Marković, Ph.D. (UC Berkeley, 2006) Implantable neuro-modulation devices, domain-specific hardware accelerators, embedded systems, design methodologies
Aydogan Ozcan, Ph.D. (Stanford, 2005) Biophotonics, imaging, nonlinear optics
Sudhakar Pamarti, Ph.D. (UC San Diego, 2003) Analog, mixed-signal, and RF-integrated circuit design; signal processing techniques to improve circuit design
Gregory J. Pottie, Ph.D. (McMaster U., Canada, 1988) Communication systems and theory with applications to wireless sensor networks
Yahya Rahmat-Samii, Ph.D. (U. Illinois, 1975) Satellite and ground communication antennas, personal communication antennas including handheld antennas, antennas for medical applications, cubesat and smallsat antennas, antennas for remote sensing and radio astronomy applications, advanced numerical and global optimization techniques in electromagnetics, frequency selective surfaces and electromagnetic band gap structures, novel integrated and fractal antennas, 2-D printed antennas, near-field antenna measurements and diagnostic techniques, electromagnetic theory
Behzad Razavi, Ph.D. (Stanford, 1992) Analog, RF, and mixed-signal integrated circuit design, dual-standard RF transceivers, phase-locked systems and frequency synthesizers, A/D and D/A converters, high-speed data communication circuits
Vwani P. Roychowdhury, Ph.D. (Stanford, 1989) Models of cognitive radio and distributed processing systems, quantum computing and information processing, circuits and computing paradigms for nanoelectronics and molecular electronics, adaptive and learning algorithms, nonparametric methods and algorithms for large-scale information processing, combinatorics and complexity, and information theory
Henry Samueli, Ph.D. (UCLA, 1980) VLSI implementation of signal processing and digital communication systems, high-speed digital integrated circuits, digital filter design
Ali H. Sayed, Ph.D. (Stanford, 1992) Adaptive systems, statistical and digital signal processing, estimation theory, signal processing for communications, linear system theory, interplays between signal processing and control methodologies, fast algorithms for large-scale problems
Stefano Soatto, Ph.D. (Caltech, 1996) Computer vision, systems and control theory, detection and estimation, robotics, system identification, shape analysis, motion analysis, image processing, video processing, autonomous systems
Jason L. Speyer, Ph.D. (Harvard, 1968) Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics
Mani B. Srivastava, Ph.D. (UC Berkeley, 1992) Wireless networking, embedded computing, networked embedded systems, sensor networks, mobile and ubiquitous computing, low-power and power-aware systems
Paulo Tabuada, Ph.D. (Technical U. Lisbon, Portugal, 2002) Real-time, networked, embedded control systems; mathematical theory including discrete-event, timed, and hybrid systems; geometric nonlinear control; algebraic/categorical methods
Lieven Vandenberghe, Ph.D. (Katholieke U. Leuven, Belgium, 1992) Optimization in engineering and applications in systems and control, circuit design, and signal processing
Mihaiela van der Schaar, Ph.D. (Eindhoven U. Technology, Netherlands, 2001) Multimedia processing and compression, multimedia networking, multimedia communications, multimedia architectures, enterprise multimedia streaming, mobile and ubiquitous computing
John D. Villasenor, Ph.D. (Stanford, 1989) Communications, signal and image processing, configurable computing systems, and design environments
Kang L. Wang, Ph.D. (MIT, 1970) Nanoelectronics and optoelectronics, nano and molecular devices, MBE and superlattices, micro and nanoelectromechanical systems, quantum information
Yuaxun Ethan Wang, Ph.D. (U. Texas Austin, 1999) Smart antennas, RF and microwave power amplifiers, numerical techniques, DSP techniques for microwave systems, phased arrays, wireless and radar systems, microwave integrated circuits
Richard D. Wesel, Ph.D. (Stanford, 1996) Communication theory and signal processing with particular interests in channel coding, including turbo codes and trellis codes, joint algorithms for distributed communication and detection
Benjamin Williams, Ph.D. (MIT, 2003) Development of terahertz quantum cascade lasers
Chee Wei Wong, Sc.D. (MIT, 2003) Ultrafast and nonlinear optics, quantum communications and computing, compact optical systems, quantum photonics, 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
C.-K. Ken Yang, Ph.D. (Stanford, 1998)
High-performance VLSI design, digital and mixed-signal circuit design

Professors Emeriti
Frederick G. Allen, Ph.D. (Harvard, 1956)
Semiconductor physics, solid-state devices, surface physics

Francis F. Chen, Ph.D. (Harvard, 1954)
Radio frequency plasma sources and diagnostics for semiconductor processing

Babak Daneshrady, Ph.D. (UCLA, 1993)
Digital VLSI circuits: wireless communication systems, high-performance communication integrated circuits for wireless applications

Harold R. Fettermann, Ph.D. (Cornell, 1968)
Optical millimeter wave interactions, high-frequency optical polymer modulators and applications, solid-state millimeter wave structures and systems, biomedical applications of lasers

Stephen E. Jacobsen, Ph.D. (UC Berkeley, 1968)
Operations research, mathematical programming, nonconvex programming, applications of mathematical programming to engineering and engineering/economic systems

Rajeev Jain, Ph.D. (Katholieke U. Leuven, Belgium, 1985)
Design of digital communications and digital signal processing circuits and systems

William J. Kaiser, Ph.D. (Wayne State, 1983)
Research and development of new microsensor and microinstrumentation technology for industry, science, and biomedical applications; development and applications of new atomic-resolution scanning probe microscopy methods for microelectronic device research

Alan Laub, Ph.D. (U. Minnesota, 1974)
Numerical linear algebra, numerical analysis, condition estimation, computer-aided control system design, high-performance computing

Nhan N. Levan, Ph.D. (Monash U., Australia, 1966)
Control systems, stability and stabilizability, errors in dynamic systems, signal analysis, wavelets, theory and applications

Dee-Son Pan, Ph.D. (Caltech, 1977)
New semiconductor devices for millimeter and RF power generation and amplification, transport in small geometry semiconductor devices, generic device modeling

Izhak Rubin, Ph.D. (Princeton, 1970)
Telecommunications and computer communication systems and networks, mobile wireless networks, multimedia IP networks, UAV/UGV-aided networks, integrated system and network management, C4ISR systems and networks, optical networks, network simulations and analysis, traffic modeling and engineering

Frederick W. Schott, Ph.D. (Stanford, 1949)
Electromagnetics, applied electromagnetics

Oscar M. Stafsudd, Ph.D. (UCLA, 1967)
Quantum electronics: IR lasers and nonlinear optics; solid-state: IR detectors

Gabor C. Temes, Ph.D. (U. Ottawa, Canada, 1961)
Analog MOS integrated circuits, signal processing, analog and digital filters

Chand R. Viswanathan, Ph.D. (UCLA, 1964)
Semiconductor electronics: VLSI devices and technology, heterostructure semiconductor devices, monolithic integration of heterostructure devices, monolithic integration of heterostructure semiconductor devices

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 and emerging 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 to understand solid-state devices, including elementary quantum theory, Fermi energies, and concepts of electrons in solids. Discussion of electrical properties of semiconductors leading to operation of junction devices. Letter grading. Mr. Jalali, Mr. Williams (FSP)

2H. Physics for Electrical Engineers (Honors). (4) Formerly numbered Electrical Engineering 2H) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: Physics 1C. Honors course parallel to course 2. Letter grading. Mr. Williams (W)

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 telecommunications, electrical grid, automatic computing and control, and enabling device technology. Research frontiers of electrical engineering. Introduction to measurement and design of electrical circuits. Letter grading. Mr. Pottie (FSP)

10. Circuit Theory (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 32A, Physics 1B, Corequisites: course 11L (recommended only for Computer Science and Engineering and Electrical Engineering majors), Mathematics 33B. Introduction to linear circuit analysis. Resistive circuits, capacitors, inductors and ideal transformers, Kirchhoff laws, node and loop
100. Electrical and Electronic Circuits. (4) (Formerly numbered Electrical Engineering 100.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: Mathematics 33A, 33B, and Mechanical and Aerospace Engineering 82, Physics 1C. Not open to credit for students with credit for course 110. Electrical quantities, linear circuit elements, circuit signals, waveforms, transient and steady state circuit behavior, diodes and transistors, small signal models, and operational amplifiers. Letter grading. Mr. Ramadan (F,Sp).

101A. Engineering Electromagnetics. (Formerly numbered Electrical Engineering 101A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Mathematics 32A and 32B, or 33A and 33B, Physics 1C. Electromagnetic field concepts, wave propagation, transmission lines, 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. Electromagnetics. (Formerly numbered Electrical Engineering 101B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 101A. Time-varying fields, Maxwell's equations, plane wave propagation and interaction with media, energy flow and Poynting vector, guided waves in waveguides, phase and group velocity, radiation and antennas. Letter grading. Mr. Wang (W,Sp).


110. Circuit Theory II. (4) (Formerly numbered Electrical Engineering 110.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisites: courses 10, 116 (or Computer Science M51A), 102. Corequisite: course 111L (enforced only for Computer Science and Engineering and Electrical Engineering majors). Mathematical modeling in design and analysis, AC steady state analysis, AC steady state power, network functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis, circuit design, and implementation. Letter grading. Mr. Abidi (Sp).

110H. Circuit Theory II (Honors). (4) (Formerly numbered Electrical Engineering 110H.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 10, 116 (or Computer Science M51A), 102. Corequisite: course 111L, Sinusoidal excitation and phasors, AC steady state analysis, AC steady state power, network functions, poles and zeros, frequency response, mutual inductance, ideal transformer, application of Laplace transforms to circuit analysis, circuit design, and implementation. Letter grading. Mr. Abidi (Sp).

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

111L. Laboratories II. (1) (Formerly numbered Electrical Engineering 111L.) Lecture, one hour; laboratory, one hour; outside study, one hour. Enforced requisite: courses 10, 111L. Enforced corequisite: course 110. Experiments with basic circuits containing resistors, capacitors, inductors, transformers, and op-amps. Steady state power analysis, frequency response principles, op-amp-based circuit synthesis, and two-port network principles. Letter grading. 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 110. Complete 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 power system analysis. Application to power system transient dynamics. Letter grading. Mr. Tabuada (F).


113DA-113DB. Digital Signal Processing Design. (4) (Formerly numbered Electrical Engineering 113DA-113DB.) Real-time implementation of digital signal processing algorithms. Design of digital signal processing 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 communication, speech, audio, or video using DSP chip. 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 113DA). 113DB. Laboratory, four hours; outside study, eight hours. Enforced requisites: courses 113DA, 113B. Completion of projects begun in course 113DA. Letter grading. Mr. Daneshgar (113DA in F,W; 113DB in W,Sp).

114. Speech and Image Processing Systems Design. (4) (Formerly numbered Electrical Engineering 114.) Lecture, three hours; discussion, one hour; lab, three hours; outside study, seven hours. Requisites: course 110. Speech production, digitization, encoding, and data transmission, aliasing, digital filtering, sinusoidal oscillators, Fourier transforms, and finite wordlength effects. Course project involving original design and implementation of signal processing systems for speech and image processing tasks. Letter grading. Ms. Fragouli, Mr. Villasenor (F).

115A. Analog Electronic Circuits I. (4) (Formerly numbered Electrical Engineering 115A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 110. Review of the physics and operations of diodes and bipolar and MOS transistors. Equivalent circuits and models of semiconductor devices. Analysis and design of single-stage amplifiers, feedback techniques for image enhancement, filtering, and transformation in second half. Experiments involving A/D and D/A converters and digital signal analysis. Operational amplifier systems. Letter grading. Mr. Abidi, Mr. Daneshgar (F).

115AL. Analog Electronics Laboratory I. (2) (Formerly numbered Electrical Engineering 115AL) Laboratory, four hours; outside study, two hours. Enforced requisite: courses 110L or 111L, 115A. Experimental determination of device characteristics, resistive diode circuits, single-stage amplifiers, compound transistors, feedback techniques for image enhancement, filtering, and transformation in second half. Experiments involving A/D and D/A converters, operational amplifiers, and operational amplifier circuits. Introduction to hands-on design experience based on individual student hardware and software design and implementation platforms. Letter grading. Mr. Abidi (Sp).


115C. Digital Electronic Circuits. (4) (Formerly numbered Electrical Engineering 115C.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 110. Review of 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, flipflops/ latch, counters), arithmetic, and design 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. Computer-aided design, communication circuits, power electronics, and instrumentation and measurement and may entail simul-
design-oriented analysis and rigorous approach to

tion-based design projects. Emphasis throughout on

(4) (Formerly numbered Electrical Engineering M116C.)

bilities; low voltage, high current, and speed; digital

M116L. Introductory Digital Design Laboratory. (2)

(For M113L, 119L.) Introductory Digital Design Laborato-


(Formerly numbered Electrical Engineering M119.) (Same as Computer Science M119.)

M121B. Principles of Semiconductor Device Design. (4)

(Formerly numbered Electrical Engineering 121B.)

M121DA-121DB. Semiconductor Processing and Device Design. (4-4)

(Formerly numbered Electrical Engineering 121DA-121DB.) Design fabrication and characterization of devices. Students perform various processing tasks such as wafer preparation, oxidation, diffusion, metallization, and photolithography. Introduction to CAD tools used in integrated circuit processing and device design. Device structure optimization tool based on MEDICI; process integration tool based on SUPREM. Course familiarizes students with those tools. Using CAD tools, CMOS process integration to be designed. 121DA Lecture, four hours; laboratory, four hours; outside study, eight hours. Enforced requisite: course 121B or one course from M119. Letter grading. Mr. Lin (F, W, Sp)

123A. Fundamentals of Solid-State I. (4) (Formerly numbered Electrical Engineering 123A.) Lecture, three hours; outside study, eight hours. Enforced requisite: course 121B. Letter grading. Mr. Wang (W, Sp)

123B. Fundamentals of Solid-State II. (4) (Formerly numbered Electrical Engineering 123B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 123A. Discussion of solid-state properties, lattices, vibrations, thermal conduct, dielectric, magnetic, and superconducting properties. Letter grading. Mr. K.L. Wang (Not offered 2020-21)

128B. Principles of Nanoelectronics. (4) (Formerly numbered Electrical Engineering 128B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: Physics 11C. Introduction to fundamentals of nanoelectronics and nanosystems. Principles of fundamental quantities: electron charge, effective mass, Bohr magneton, and the like, and the energy band structure, as well as theorems and approximations. From these nanoscale components, discussion of basic behaviors of nanosystems such as analysis of dynamics, variability, and statistical representation of nanoscale systems. Enforced requisites: course 123A. 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. 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. Applications to communication, control, and signal processing. Introduction to computer simulation and generation of random events. Letter grading. Mr. Roychowdhury (FW)

132A. Introduction to Communication Systems. (4) (Formerly numbered Electrical Engineering 132A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 102, 113, 131A. Review of basic probability, basics of hypothesis testing, sufficient statistics and waveform communication, signal-design tradeoffs for digital communications, basics of error control coding, inter-symbols interference channels and orthogonal frequency-division multiplexing (OFDM), basics of wireless communications. Letter grading. Mr. Digavi (W, Sp)

132B. Data Communications and Telecommunication Networks. (4) (Formerly numbered Electrical Engineering 132B.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: courses 102, 113, 131A. Layered communications architectures. Queueing system modeling and analysis. Error control, flow control, congestion control, packet switching, circuit switching, and routing. Network performance measurements. Multiple access communications: TDMA, FDMA, polling, random access. Local, metropolitan, wide area, integrated service networks. Letter grading. Mr. Rubin (F)

133A. Applied Numerical Computing. (4) (Formerly numbered Electrical Engineering 133A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 131A; and Civil and Mechanical Aerospace Engineering M20 or Computer Science 31 or Mechanical and Aerospace Engineering M20. Introduction to numerical computing/analysis; analytic formulations versus numerical solutions; floating-point representations and rounding errors. Review of MATLAB; mathematical software. Linear equations; LU factorization; bounds on error; iterative methods for solving linear equations; conditioning and stability; complexity. Iteration and approximation; splines. Zeros and roots of nonlinear equations. Linear and non-linear optimization; vectorization; statistical interpretation. Numerical optimization; Newton method; nonlinear least squares. Numerical quadrature. Solving ordinary differential equations. Eigenvalues and singular values; QR algorithm; statistical applications. Letter grading. Mr. Vandenberge (W)

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. Simulation of dynamical systems. Algorithms for ordinary differential and difference equations. Fourier analysis and singular value decomposition (SVD) and random number generators. Simulation of stochastic systems, Monte Carlo methods. Constrained optimization; applications of optimization to engineering de-

sign, modeling, and data analysis. Introduction to discrete-event simulation and rigorous techniques in thinking, complexity. Integration of mathematical software in applications. Letter grading. Mr. Vandenberge (Not offered 2020-21)

134. Graph Theory in Engineering. (4) (Formerly numbered Electrical Engineering 141.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 102. Mathematical modeling of physical control systems in form of differential equations and transfer functions. Design problems, system performance indices of feedback control systems via classical techniques, root-locus and frequency-domain methods. Computer-aided solution of design problems from real world. Letter grading. Mr. Tabuada (Not offered 2020-21)

142. Linear Systems: State-Space Approach. (4) (Formerly numbered Electrical Engineering 142.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 102. State-space methods of linear control synthesis, with application to problems in networks, control, and system modeling. Letter grading. Mr. Tabuada (Not offered 2020-21)

C143A. Neural Signal Processing. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 131A, Mathematics 33A. Topics include fundamental properties of electrical activity in neurons; technology for measuring neural activity; spiking statistics and Poisson processes; generative models and classification; regression and Kalman filtering; principal components analysis, factor analysis, and expectation maximization. Con-

C147. Neural Networks and Deep Learning. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisites: courses 131A, 133A or 205A, and 143A, or equivalent. Review of machine learning concepts: maximum likelihood, supervised classification; neural network architectures; backpropagation; regularization for training neural networks; optimization for training neural networks; convolutional neural networks; practical CNN architectures; deep learning libraries in Python; recurrent neural networks, backpropagation through time, long short-term memory and gated recurrent units; varia-

M146. Introduction to Machine Learning. (4) (Formerly numbered Electrical Engineering M146.) (Same as Computer Science M146.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 131A or Civil and Environmental Engineering 110 or Mathematics 170A or 170E or Statistics 100A, Computer Science 33. Introduction to the breadth of data science and modeling. Data sources, principles of operation of common tools for data analysis, and application of tools and models to data gathering and analysis. Topics in-

C147. Neural Networks and Deep Learning. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 131A, 133A or 205A, and 143A, or equivalent. Review of machine learning concepts: maximum likelihood, supervised classification; neural network architectures; backpropagation; regularization for training neural networks; optimization for training neural networks; convolutional neural networks; practical CNN architectures; deep learning libraries in Python; recurrent neural networks, backpropagation through time, long short-term memory and gated recurrent units; varia-

M153. Introduction to Microscale and Nanoscale Manufacturing. (4) (Formerly numbered Electrical Engineering M153.) (Same as Bioengineering M153, Chemical Engineering M153, and Mechanical and Aerospace Engineering M183B.) Lecture, three hours; laboratory, four hours; outside study, five hours. Enforced requisites: Physics 20A, Mathematics 1A, 1B, 1C, 4A, 4B. Introduction to general manu-
facturing methods, mechanisms, and constraints, and microfabrication. Focus on theoretical concepts, physics, and instruments of various microfabrication and nanofabrication techniques that have been broadly applied in industry and academia, including various technologies, physical and chemical deposition methods, and physical and chemical etching methods. Hands-on experience for fabricating microstructures and nanOSTRUCtURSts in modern cleanroom environments. Letter grading. Mr. Rahmat-Samii (Sp)

162A. Wireless Communication Links and Antennas. (4) (Formerly numbered Electrical Engineering 162A.) Lecture, four hours; discussion, two hours; outside study, seven hours. Enforced requisite: course 101B. Basic properties of transmitting and receiving antennas and antenna arrays. Array synthesis. Adaptive arrays. Fis transmission formula, radar equations. Cell-site and mobile antennas, bandwidth, noise. Noise in communication systems (transmission lines, antennas, atmospheric, etc.). Cell-site and mobile antennas, cell coverage for signal and traffic, interference, multipath fading, ray bending, and other propagation phenomena. Letter grading. Mr. Chiou (F, W, Sp)

163A. Introductory Microwave Circuits. (4) (Formerly numbered Electrical Engineering 163A.) Lecture, four hours; laboratory, three hours; outside study, seven hours. Enforced requisite: course 101B. Design of radio frequency circuits and systems, with emphasis on both theoretical foundations and hands-on experience and practical circuitry related to cost, performance, ease of use, manufacturability, testing, and other real-world issues. Oral and written presentations of project results required. In Progress (164DA) and letter (164DB) grading. Mr. Chang, Mr. Itoh, Mr. Razavi (Not offered 2020-21)

170A. Principles of Microwave Engineering. (Formerly numbered Electrical Engineering 170A.) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisites: courses 2, 101A. Development of solid foundation on essential principles of photonics from ground with up minimum prior knowledge on this subject. Topics include optical properties of materials, optical wave propagation and modes, optical interferometers and resonators, optical coupling and modulation, optical absorption and emission, principles of lasers and light-emitting diodes, and optical detection. Letter grading. Mr. Liu (EW)

170B. Photonic Devices and Circuits. (4) (Formerly numbered Electrical Engineering 170B.) Lecture, four hours; recitation, one hour; outside study, seven hours. Enforced requisite: course 170A. Coverage of core knowledge of practical photonic devices and circuits. Topics include optical waveguides, optical fi-

180A-180B. Systems Design. (4–4) (Formerly numbered Electrical Engineering 180A-180B.) Limited to senior Electrical Engineering majors. Advanced systems design integrating communications, control, and signal processing subsystems. Introduction to advanced topics related to projects through lecture and laboratories. Open-ended projects vary each offering. Student teams create high-performance designs that manage trade-offs among subsystem components, including cost, performance, ease of use, and other real-world constraints. Oral and written presentation of project results. 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 each offering. Student teams create high-performance designs that manage trade-offs among subsystem components, including cost, performance, ease of use, and other real-world constraints. Oral and written presentation of project results. Letter grading. Mr. Ozcan (Sp)
201D. Design in Nanoscale Technologies. (Formerly numbered Electrical Engineering 201D.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 115C. Challenges of digital circuit design and layout in deeply scaled technologies, with focus on current and advanced topics in one or more aspects of circuits and embedded systems, such as mixed-mode (analog/digital), power and thermal management; power-performance scaling and energy-aware system design, timing synchronization, power consumption. Letter grading.

Mr. Sayed (Sp)

209AS. Special Topics in Circuits and Embedded Systems. (Formerly numbered Electrical Engineering 209AS.) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: prior training in probability theory, random processes, and linear algebra. Recommended requisites: courses M205A, M205B. Mean-square-error estimation and filters, least-squares estimation and filters, steepest-descent algorithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance; algorithms for adaption and learning, adaptive filters, learning and classification, optimization. Letter grading.

Mr. Sayed (Sp)

210B. Inference over Networks. (Formerly numbered Electrical Engineering 210B.) Lecture, four hours; outside study, eight hours. Preparation: prior training in probability theory, random processes, linear algebra, and adaptation. Enforced requisite: course 210A. Adaptation and learning, detection on networks. Steepest-descent algorithms, stochastic-gradient algorithms, convergence, stability, tracking, and performance analyses. Distrib-

Mr. Kadambi, Mr. Villasenor (W)


Mr. Sayed (Not offered 2020-21)

215A. Analog Microsystem Design. (4) Formerly numbered Electrical Engineering 215A. Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 215A. Analog and digital design of microsystems. Analysis of physical limitations of integrated circuits design. Topics in microelectronics include design of CMOS, BiCMOS, and Bipolar ICs. Special emphasis on high-performance analog circuit design. Letter grading.

Mr. Abidi, Mr. Razavi (Sp)


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, M216A. Analysis and design of circuits for synchronization and communication for VLSI systems. Use of both digital and analog techniques to improve data rates of electronics between functional blocks, chips, and systems. Advanced clocking methodologies, phase-locked loop design for clock generation, and high-performance direct current transmitters, receivers, and timing recovery circuits. Letter grading.

Mr. Pamarti (Sp)

M216A. Design of VLSI Circuits and Systems. (4) Formerly numbered Electrical Engineering M216A. Same as Computer Science M216A. Lecture, four hours; discussion, two hours; laboratory, four hours; outside study, two hours. Requisites: courses M16 or Computer Science M215A, and 115A. Recommended: course 115C. Use of advanced design charts in computer systems. Fundamental design techniques that can be used to implement complex integrated systems on chips. Letter grading.

Mr. Markovic (F)

216B. VLSI Signal Processing. (4) Formerly numbered Electrical Engineering 216B. Lecture, four hours; outside study, eight hours. Advanced concepts in VLSI signal processing, with emphasis on architecture design and optimization within block-based description that can be mapped to hardware. Fundamental concepts from digital signal processing (DSP) theory, architecture, and circuit design applied to complex DSP algorithms in emerging applications for personal communications and healthcare. Letter grading.

Mr. Markovic (Not offered 2020-21) M216C. LSI in Computer System Design. (4) Formerly numbered Electrical Engineering M216C. (Same as Computer Science M216C.) Lecture, four hours; laboratory, four hours; outside study, four hours. Requisite: course M216A. LSI/VLSI design and application in computer systems. In-depth studies of VLSI architectures and VLSI design tools. Letter grading.

Mr. Ozcan (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 how different cooperative and noncooperative games among agents can be constructed and analyzed and how the agents 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 determine their optimal actions in these distributed, informationally decentralized environments, agents need to learn and model directly or implicitly other agents' responses to their actions. Letter grading.

Mr. Yang (W)

215C. Analysis and Design of RF Circuits and Systems. (4) Formerly numbered Electrical Engineering 215C. Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 215A. Principles of RF circuit and system design, with emphasis on modeling in VLSI technologies. Basic concepts, communications background, transceiver architectures, low-noise amplifiers and mixers, oscillators, frequency synthesizers, power amplifiers. Letter grading.

Mr. Abidi, Mr. Razavi (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 devices. Letter grading.

Mr. K.L. Wang, Mr. Wu (W)

221B. Physics of Semiconductor Devices II. (4) Formerly numbered Electrical Engineering 221B. Lecture, four hours; outside study, eight hours. Principles and design considerations of field effect devices and charge-coupled devices. Letter grading.

Mr. Wu (Sp)

221C. Microwave Semiconductor Devices. (4) Formerly numbered Electrical Engineering 221C. Lecture, four hours; discussion, one hour; outside study, seven hours. Microwave devices and circuits, design considerations of microwave solid-state devices: Schottky barrier mixer diodes, IMPATT diodes, transferred electron devices, tunnel diodes, microwave transistors. Letter grading.

Mr. K.L. Wang, Mr. Wu (Not offered 2020-21)
230A. Detection and Estimation in Communication. (4) (Formerly numbered Electrical Engineering 230A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Application of estimation and detection concepts to 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 signal, Rayleigh, and Neyman-Pearson (NP) criteria; signal-to-noise ratio (SNR) and error probability evaluations. Introduction to Monte Carlo simulations. Letter grading.

230B. Digital Communication Systems. (4) (Formerly numbered Electrical Engineering 230B.) Lecture, four hours; outside study, eight hours. Requisites: courses 132A, 230A. Principles and practical techniques of communication, at physical, data-link, and network layers; multiple access protocols; new wireless standards; techniques for security, authentication, and privacy. Letter grading.

230C. Signal Processing in Communications. (4) (Formerly numbered Electrical Engineering 230C.) Lecture, four hours; outside study, eight hours. Requisites: courses 131A, 230A. Concepts and implementations of signal processing in communication and signal processing systems. Spectral analysis using Fourier transform and windowing, parametric modeling, eigen-decomposition methods, time-frequency analysis, wavelet transform, and subband processing. Array processing using beamforming for SNIR enhancement, smart antenna, and source separation and localization. Introduction to compressive sampling and applications. Letter grading.}

231A. Information Theory: Channel and Source Coding. (4) (Formerly numbered Electrical Engineering 231A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 231A. Point-to-point multiple-input, multiple-output (MIMO) wireless channels: capacity and outage; space-time block codes and trellis codes; channel capacity versus distortion in lossy communication, and basics of information theory for networks. Letter grading.

231B. Information Theory and Applications. (4) (Formerly numbered Electrical Engineering 231B.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 231A. Point-to-point multiple-input, multiple-output (MIMO) wireless channels: capacity and outage; space-time block codes and trellis codes; channel capacity versus distortion in lossy communication, and basics of information theory for networks. Letter grading.


232B. Queuing Systems and Intelligent Transportation Networks. (4) (Formerly numbered Electrical Engineering 232B.) Lecture, four hours; outside study, eight hours. Requisite: course 131A or equivalent. Analysis, design, and traffic management of autonomous mobile systems. System and network layer functionalities. Letter grading.


233. Wireless Communications System Design, Modeling, and Implementation. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 113. Covers algorithms, architectures, transceivers, physical, and network layer functionalities. Topics include wireless channel modeling, single-carrier and multi-carrier systems, multiple antenna systems, radio impairments and their correction, architectures and circuits designs, wideband spectrum sensing, wideband signaling, cognitive radio, massive multiple-input, multiple-output (MIMO) systems, and applications in 5G and Internet of Things (IoT) communication. Letter grading.
tion, Markov decision processes, combinatorial optimization, computer science, letter grading.
Mr. Vandenberge (Not offered 2020-21)

238. Multimedia Communications and Processing.
(Formerly numbered Electrical Engineering 238.) Lecture, four hours; discussion, one hour; outside study, seven hours. Special topics in one or more aspects of signal processing, such as communication, computer science, information theory, multimedia, computer networking, optimization, signal processing, telecommunications, and VLSI. May be repeated for credit with topic change. S/U or letter grading.

Ms. Fragoili (Not offered 2020-21)

M240A. Linear Dynamic Systems.
(Formerly numbered Electrical Engineering 240A.) Lecture, four hours; discussion, eight hours. Special topics in linear system theory, linear time-invariant (LTI) systems, linear parameter-varying (LPV) systems, and linear time-varying (LTV) systems. May be repeated for credit with topic change. S/U or letter grading.
Mr. Tabuada (F)

241A. Stochastic Processes.
Mr. Diggavi (F)

M242A. Nonlinear Dynamic Systems.
(Formerly numbered Electrical Engineering 242A.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 131A. Technical concepts and principles with examples that emphasize the role of the observer in state estimation. Topics include estimation, observer design, and observer performance. Letter grading.
Mr. Tabuada (W)

C243A. Neural Signal Processing.
(Formerly numbered Electrical Engineering 243A-B.) Lecture, four hours; discussion, one hour; outside study, eight hours. Topics include machine learning concepts, maximum likelihood, supervised learning concepts; maximum likelihood; supervised learning in neural networks; backpropagation through time; long short-term memory and gated recurrent units; variational autoencoders; generative adversarial networks (GAN’s). Discussion of reinforcement learning. Letter grading.

C247. Neural Networks and Deep Learning.
(Formerly numbered Electrical Engineering 247.) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 131A, 133A or 205A, and M146, or equivalent. Review of machine learning concepts; maximum likelihood; supervised classification; neural network architectures; back-propagation; regularization for training neural networks; optimization for training neural networks; convolutional neural networks; practical CNN architectures; deep learning libraries in Python; recurrent neural networks; backpropagation through time, long short-term memory and gated recurrent units; variational autoencoders; generative adversarial networks; adversarial examples and training. Concurrently scheduled with course C147. Letter grading.
Mr. Kao (W)

M248S. Seminar: Systems, Dynamics, and Control Topics.
(Formerly numbered Electrical Engineering 248S.) Lecture, four hours; discussion, one hour; outside study, six hours. Limited to graduate engineering students. Presentations of research topics by leading academic researchers from fields of systems, dynamics, and control. Students who work in these fields present their papers and results. S/U grading.
Mr. Tabuada (Not offered 2020-21)

M250B. Microelectromechanical Systems (MEMS) Fabrication.
(Formerly numbered Electrical Engineering 250B.) Lecture, three hours; discussion, one hour; outside study, eight hours. Requisite: course M153. Advanced discussion of micromachining processes used to construct MEMS. Coverage of many lithographic, deposition, etching, and etching processes, as well as their combination in process integration. Materials issues such as chemical resistance, corrosion, mechanical properties, and residual/intrinsic stress. Letter grading.
Mr. Candler (Not offered 2020-21)

(Formerly numbered Electrical Engineering 252.) Lecture, four hours; discussion, one hour; outside study, seven hours. Introduction to MEMS design. Design methods, design rules, simulation, actuation (piezoelectric, electromagnetic), and microactuators. Designing MEMS to be produced with both foundry and nonfoundry processes. Computer-aided design for MEMS. Design project required. S/U or letter grading.

M255. Neuroengineering.
(Formerly numbered Electrical Engineering 255.) Lecture, four hours; laboratory, three hours; outside study, five hours. Requisites: Mathematics 32A, Physics 1B or 5C. Introduction to principles and technologies of bioelectricity and neural signal recording, processing, and stimulation. Topics include bioelectricity, electrophysiology (action potentials, EEG, ECOG), intracellular and extracellular recording, microelectrode technology, neural signal processing (neural signal frequency bands, filtering, spike detection, sorting, stimulus artifact removal), brain-computer interfaces, deep-brain stimulation, and prosthetics. Letter grading.
Mr. Markovic (F)

M256A-M256B-M256C. Evaluation of Research Literature in Neuroengineering. (2-2-2) (Formerly numbered Electrical Engineering 256A-M256B-M256C.) Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanostructures, top-down and bottom-up (self-assembly) nanofabrication; nanochip characterization; nanomaterials, nanoelectronics, and nanobiodetection technology. Introduction to knowledge and techniques in nano areas to understand silicon physical principles behind nanotechnology and inspire students to create new ideas in multidisciplinary nano areas. Letter grading.
Mr. Chen (Not offered 2020-21)

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 characteristics of electromagnetic dynamics and their applications to modern engineering problems. Vector calculus in generalized coordinate system. Solutions of wave equation and special functions. Requisite: radiation, transmission, and polarization. Vector potential, duality, Maxwell’s equations, and coordinate invariance theorems. Scattering from cylinder, half-plane, wedge, and sphere, including radar cross-section characterization. Green’s functions in electromagnetics and dyadic calculus. Letter grading.
Mr. Rahmat-Samii (F)

260B. Advanced Engineering Electrodynamics.
Mr. Rahmat-Samii (Not offered 2020-21)

261. Microwave and Millimeter Wave Circuits.
(Formerly numbered Electrical Engineering 261.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 101B, 162A. Advanced treatment of concepts and numerical techniques in electromagnetic circuits and microstrip circuits, microstrip, slotline, stripline, dielectric waveguide distributed circuits, with applications in microwave and millimeter wave integrated circuits, substrates, and materials. Letter grading.
Mr. Itoh (W)
262. Antenna Theory and Design. (4) (Formerly numbered Electrical Engineering 262.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 162A. Antenna patterns. Sum and difference patterns. Optimum designs for rectangular and circular arrays. Antenna orientation. Discrete arrays. Mutual coupling. Design of feeding networks. Letter grading. Mr. Rahmat-Samii (F) 263. Reflector Antennas Synthesis, Analysis, and Measurement. (4) (Formerly numbered Electrical Engineering 263.) Lecture, four hours; discussion, one hour; outside study, eight hours. Requisites: courses 260A, 260B. Reflector pattern analysis techniques. Single and multi-reflector antenna configurations. Reflector synthesis techniques. Reflector feeds. Reflector tolerance studies, including systematic and random errors. Array-fed reflector antennas. Near-field measurement techniques. Compact range concepts. Microwave diagnostictic techniques. Modern satellite and ground antenna applications. Letter grading. Mr. Rahmat-Samii (Not offered 2020-21) 266. Computational Methods for Electromagnetics. (4) (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 and finite-element methods. Method of moments. Applications include transmission lines, resonators, integrated circuits, solid-state device modeling, electromagnetic scattering, and antennas. Letter grading. Mr. Shah (Not offered 2020-21) 270. Applied Quantum Mechanics. (4) (Formerly numbered Electrical Engineering 270.) Lecture, four hours; discussion, one hour; outside study, seven hours. Preparation: courses 162A, 163A. Computational techniques for partial differential equations and finite-element methods. Method of moments. Applications include transmission lines, resonators, integrated circuits, solid-state device modeling, electromagnetic scattering, and antennas. Letter grading. Mr. Shah (Not offered 2020-21) 271. Classical Laser Theory. (4) (Formerly numbered Electrical Engineering 271.) Lecture, four hours; outside study, eight hours. Enforced requisite: course 270. Principles of quantum mechanics for applications in lasers, solid-state physics, and nonlinear optics. Laser cavity design. Laser instability. Applications include short laser pulse characteristics, generation, and measurement. Gain switching, Q switching, cavity dumping, and passive mode locking. Pulse compression and soliton pulse formation. Nonlinear pulse generation: soliton, additive-pulse mode locking, and parametric oscillators. Pulse measurement techniques. Letter grading. Mr. Stafuski (F) 272. Dynamics of Lasers. (4) (Formerly numbered Electrical Engineering 272.) Lecture, four hours; outside study, eight hours. Preparation: courses 162A, 163A. Focus on lasers and nonlinear optics. Laser cavity design. Laser instability. Applications include short laser pulse characteristics, generation, and measurement. Gain switching, Q switching, cavity dumping, and active mode locking. Pulse compression and soliton pulse formation. Nonlinear pulse generation: soliton, additive-pulse mode locking, and parametric oscillators. Pulse measurement techniques. Letter grading. Mr. Liu (Not offered 2020-21) 273. Nonlinear Photonics. (4) (Formerly numbered Electrical Engineering 273.) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 170A. Recommended: course 271. Nonlinear and optical switching and amplification. Coupled-wave equations, four-wave mixing, self-induced index changes, and self-phase modulation. Nonlinear photonic devices. Nonlinear guided-wave photonics and devices. Letter grading. Mr. Liu (Not offered 2020-21) 274. Optical Communication and Sensing Design. (4) (Formerly numbered Electrical Engineering 274.) Lecture, three hours; outside study, nine hours. Requisites: courses 170A and 170B or equivalent. Top-down design methodology for fiber optic communication systems, including Telecom, Datacom, and CATV. Fundamentals of digital and analog optical communication systems, fiber transmis- sion techniques, including direct and external modulation and computer-aided design. Architectural-level design of fiber optic transceiver circuits, including preamplifier, quantizer, and digital baseband. Experimental predistortion and predistortion circuits. Letter grading. Mr. Chen, Mr. Joshi (Not offered 2020-21) 279A. Special Topics in Physical and Wave Electronics. (4) (Formerly numbered Electrical Engineering 279A/S.) Lecture, four hours; discussion, on hour; outside study, eight hours. Concentration on one or more aspects of physical and wave electronics, such as electromagnetics, microwave and millimeter wave circuits, photonics and optoelectron- ics, microwave and millimeter wave systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U or letter grading. Mr. Y. Wang (W,Sp) 279BS. Seminar: Physical and Wave Electronics. (2 to 4) (Formerly numbered Electrical Engineering 279BS.) 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 physical and wave electronics. Electromagnetics, microwave and millimeter wave circuits, photonics and optoelectronics, microwave electronics, micro- and nanoelectromechanical systems, solid state, and nanotechnology. May be repeated for credit with topic change. S/U grading. Mr. Y. Wang (Not offered 2020-21) 279CS. Clean Green IGERT Brown-Bag Seminar. (1) (Formerly numbered Electrical Engineering 279CS.) Seminar, one hour. Required of students in Clean Energy for Green Industry (IGERT) Research. Literature seminar presented by graduate students and experts from around country who conduct research in energy harvest, storage, and conservation. S/U grading. Mr. Y. Wang (Not offered 2020-21) 282A. Science, Technology, and Public Policy. (4) (Formerly numbered Electrical Engineering 282A.) (Same as Public Policy CM282.) Lecture, three hours. Recent and current issues in science and technology are raising profoundly important public policy issues. Consideration of selection of critical policy issues, each of which has substantial ethical, economic, political, and scientific and technological aspects. Concurrently scheduled with course CM182. Letter grading. Mr. Villasenor (Not offered 2020-21) 282A. Plasma Waves and Instabilities. (4) (Formerly numbered Electrical Engineering 282A.) Lecture, four hours; outside study, eight hours. Requi- sites: courses 101A, and M185 or Physics M122. Wave phenomena in plasmas described by macroscopic fluid equations. Wave propagation in plasmas: waves in inhomogeneous and bounded plasmas, plasma oscillations, ion acoustic waves, cyclotron waves, hydromagnetic waves, drift waves. Rayleigh/Taylor, Kelvin/Helmholtz, universal, and stream- ing instabilities. Application to experiments in fully and partially ionized gases. Letter grading. Mr. Mori (Not offered 2020-21) 285B. Advanced Plasma Waves and Instabilities. (4) (Formerly numbered Electrical Engineering 285B.) Lecture, four hours; outside study, eight hours. Requis- its: courses M185, and 285A or Physics 222A. Introduction of intense electromagnetic waves with plasmas: waves in inhomogeneous and bounded plasmas, nonlinear wave coupling and damping, parametric instabilities, anomaly resistivity, shock waves, echoes, laser heating. Experiment on experi- mental considerations and techniques. Letter grading. Mr. Joshi (Not offered 2020-21) 285T. Seminar: Plasma Physics and Analysis. (4) (Formerly numbered Electrical Engineering 285T.) (Same as Mechanical and Aerospace Engineering M237B.) Lecture, four hours; outside study, eight hours. Supervised research in small groups or individually. Limited to graduate electrical engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be ar- ranged. May be repeated with topic change. S/U or letter grading. Mr. Mori (Not offered 2020-21) 289. MS Project Seminar. (4) (Formerly numbered Electrical Engineering 289.) Seminar, to be arranged. Required of all MS students not in thesis option. Supervised research in small groups or individually under guidance of faculty mentor. Regular meetings, culminating report, and presentation required. Individual contract required; enrollment petitions available in Office of Graduate Student Affairs. S/U grading. Mr. Mori (Not offered 2020-21) 375. Teaching Apprentice Practicum. (1 to 4) (Formerly numbered Electrical Engineering 375.) Seminar, to be arranged. Preparation; appointment personnel employment as teaching assistant, associate, or fellow. Teaching two hours per week, under active guid- ance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading. (W,Sp) 349. Teaching Apprentice Practicum. (1 to 4) (Formerly numbered Electrical Engineering 349.) Seminar, to be arranged. Preparation; appointment personnel employment as teaching assistant, associate, or fellow. Teaching two hours per week, under active guid- ance and supervision of regular faculty member responsible for curriculum and instruction at UCLA. May be repeated for credit. S/U grading. (W,Sp) 495. Teaching Preparation Seminar: Teaching and Professional Pedagogical Skills. (4) (Formerly numbered Electrical Engineering 495.) (Same as English Composition M495K.) Seminar, two hours. Limited to graduate electrical engineering students. Required of all departmental teaching assistants (TAs). May be taken concurrently while holding
Materials Science and Engineering

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Sunee Kodambaka, Ph.D.
Xiaochun Li, Ph.D.
Jaime Marian, Ph.D.
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Qibing Pei, Ph.D.
Gaurav N. Sant, Ph.D. (Henry Samueli Fellow)
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Sarah H. Tolbert, Ph.D.
Kang L. Wang, Ph.D. (Raytheon Company Professor of Electrical Engineering)
Paul S. Weiss, Ph.D. (Presidential Professor of Chemistry)
Benjamin M. Wu, D.D.S., Ph.D.
Ya-Hong Xie, Ph.D.
Jenn-Ming Yang, Ph.D.
Yang Yang, Ph.D. (Carol and Lawrence E. Tannas, Jr., Endowed Professor of Engineering)

Professors Emeriti
Alan J. Ardell, Ph.D.
Kanji Ono, Ph.D.
King-Ning Tu, Ph.D.

Assistant Professors
Amartya Banerjee, Ph.D.
Ximin He, Ph.D.
Aaswath P. Raman, Ph.D.

Adjunct Associate Professors
Eric P. Bescher, Ph.D.
Sergey Prikhodko, Ph.D.

Adjunct Assistant Professors
Magdalena Balonis-Sant, Ph.D.
Marta Pozuelo, 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 (College 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.

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:

• 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, 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; two capstone design courses (Materials Science and Engineering 140A and 140B); and two major field elective courses (8 units) from Chemical Engineering CM114, Civil and Environmental Engineering 130, 135A, Electrical and Computer Engineering 2, 123A, 123B, Materials Science and Engineering C111, C112, 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 22 or the GE Requirement web page.

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); Mathematics 1A, 1B, 1C.

The Major

Required: Electrical and Computer Engineering 100, 101A, 121B, Materials Science and Engineering 104, 110, 110L, 120, 121, 121L,
122, 130, 131L, 132, Mechanical and Aerospace Engineering 101; 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; either Materials Science and Engineering 150 or 160 and one course (4 units) from Electrical and Computer Engineering 123A, 123B, Materials Science and Engineering 150, 160; 4 laboratory units from Materials Science and Engineering 141L, 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; two capstone design courses (Materials Science and Engineering 140A and 140B); and one major field elective course (4 units) from Electrical and Computer Engineering 110, 131A, Materials Science and Engineering C11T, C112, 143A, or 162.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or the GE Requirement web page.

Graduate Study
For information on graduate admission, see Graduate Programs on page 26.

The following introductory information is based on 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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 Materials Science and Engineering offers Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Materials Science and Engineering.

Materials Science and Engineering M.S.

Areas of Study
There are three main areas in the M.S. program: ceramics and ceramic processing, electronic and optical materials, and structural materials. Students may specialize in any one of the three areas, although most students are more interested in a broader education and select a variety of courses. Basically, students select courses that serve their interests best in regard to thesis research and job prospects.

Course Requirements
Thesis Plan. Nine courses are required, of which six must be graduate courses. The courses are to be selected from the following lists, although suitable substitutions can be made from other engineering disciplines or from chemistry and physics with the approval of the departmental graduate adviser. Two of the six graduate courses may be Materials Science and Engineering 598 (thesis research).

Comprehensive Examination Plan. Nine courses are required, six of which must be graduate courses, selected from the following lists with the same provisions listed under the thesis plan. Three of the nine courses may be upper-division courses.

Materials Science and ceramic processing: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, C21T, 246D, 298.

Electronic and optical materials: Materials Science and Engineering 121, 122, 143A, 151, 161, 162, 200, 201, 210, 221, 222, 223, 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, M152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, 133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131L, 132, 140A, 140B, 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 major fields named above are described in a Ph.D. major field syllabus, each of which can be obtained in the department office.

The minor field normally embraces a body of knowledge equivalent to three courses, at least two of which are graduate courses. If students fail to satisfy the minor field requirements through coursework, a minor field examination may be taken (once only). The minor field is selected to support the major field and is usually a subset of the major field.

Written and Oral Qualifying Examinations
During the first year of full-time enrollment in the Ph.D. program, students take the oral preliminary examination that encompases 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 (60–300 keV); and a scanning electron microscope equipped with a quantitative chemical/compositional analyzer, 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)  
Electromagnetoelectric 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 electrochemical materials, energy storage, sol-gel materials and chemistry

Nasr M. Ghoniem, Ph.D. (U. Wisconsin, 1977)  
Mechanical behavior of high-temperature materials, radiation interaction with material (e.g., laser, 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)  
Nanomaterial fabrication and development, bio-nano structures

System scaling technology, advanced packaging and 3D integration, technologies and techniques for memory subsystem integration and neuromorphic computing

Chemical and physical properties of nonmetallic archaeological materials; alteration processes in archaeological vitreous materials and pigments

Synthesis, characterization, and applications of superhard metals, conducting polymers, and thermoelectrics and graphene

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

Xiaochun Li, Ph.D. (Stanford, 2001)  
Sculpturing (science-driven manufacturing), super metals by nanoparticles self-dispersion, scalable nanomanufacturing, smart manufacturing, additive manufacturing

Jaime Marian, Ph.D. (UC 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

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

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

Gaurav N. Sant, Ph.D. (Purdue, 2009)  
Development and design of sustainable low-CO2 footprint materials for infrastructure construction applications

Dwight C. Streit, Ph.D., NAE 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 nanoelectronics, magnetics and photonics, nonlinear interactions of correlated devices and nanosystems

Paul S. Weiss, Ph.D. (UC Berkeley, 1986)  
Atomic-scale surface chemistry and physics, molecular devices, nanolithography, biophysics and neuroscience, nanometer-scale electronics and storage, surface interactions, surface motion, dynamics, and direct manipulation, extending capabilities of scanning tunneling microscope, molecular-scale control and measurement of composition and properties in membranes
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 material science and new materials vital to advanced technology. Microstructural analysis and various material properties discussed in conjunction with such applications as biomedical sensors, pollution control, and microelectronics. Letter grading. Mr. Kodambaka (F)

13L. Cultural (Materials) Science Investigations in Art and Archaeology. (5) Laboratory, four hours; discussion, two hours; site visits, four hours; outside study, two hours. Introduction to portable X-ray fluorescence (XRF) and ultraviolet, visible, near infrared (UV/Vis/NIR) spectroscopy and forensic imaging, with emphasis on fundamentals of techniques, data collection and interpretation, and effects of weathering and post depositional and taphonomic processes to help answer questions related to ancient materials manufacturing technologies, materials variability, and human history. Review for techniques and analysis of materials through X-ray fluorescence spectroscopy (XRF); fiber optic reflectance spectroscopy (FORSS); and forensic multispectral imaging. 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 inquiry. Emphasizes questions for techniques and analysis of materials through X-ray fluorescence spectroscopy (XRF); fiber optic reflectance spectroscopy (FORSS); and forensic multispectral imaging. Letter grading.

110. Introduction to Materials Characterization A Laboratory. (2) Laboratory, four hours; outside study, two hours. Enforced requisites: course 104. Modern methods of materials characterization: fundamentals of crystallography, properties of X-rays, X-ray scattering methods, determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray microscopy; design of materials characterization procedures. Letter grading. Mr. Goorsky (F)

111. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered C211. Lecture, four hours; outside study, eight hours. Enforced requisites: course 104. Introduction to transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Concurrently scheduled with course C211. Letter grading. Mr. Kodambaka (W)

111L. Introduction to Materials Characterization B Laboratory. (2) Laboratory, four hours; outside study, two hours. Enforced requisites: course 111. Experimental techniques and analysis of materials through electron microscopy. Determination of morphology, microstructure, and crystallinity of samples. Letter grading.


M105. Principles of Nanoscience and Nanotechnology. (4) Same as Engr 115A. 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 (typically with feature sizes below few hundred nanometers) explained using basic principles of 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. Letter grading. Mr. Kodambaka (F)

110. Introduction to Materials Characterization A Laboratory. (2) Laboratory, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 104. Modern methods of materials characterization: fundamentals of crystallography, properties of X-rays, X-ray scattering methods, determination of crystal structures; phase diagram determination; high-resolution X-ray diffraction methods; X-ray microscopy; design of materials characterization procedures. Letter grading. Mr. Goorsky (F)

111. Introduction to Materials Characterization B (Electron Microscopy). (4) Formerly numbered C211. Lecture, four hours; outside study, eight hours. Enforced requisites: course 104. Introduction to transmission electron microscopy; reciprocal lattice, electron diffraction, stereographic projection, direct observation of defects in crystals, replicas; scanning electron microscopy; emissive and reflective modes; chemical analysis; electron optics of both instruments. Concurrently scheduled with course C211. Letter grading. Mr. Kodambaka (W)


120. Physics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: courses 104, 110 (or Chemistry 113A). Introduction to electrical, optical, and magnetic properties of solids. Electron microscopy: introduction to band theory and Schr"{o}dinger wave equation. Crystal bonding and lattice vibrations. Mechanisms and characteristics of absorption, reflectivity, optical absorption, magnetic behavior, dielectric properties, and p-n junctions. Letter grading. Mr. Y. Yang (W)

121. Materials Science of Semiconductors. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: course 120. Structure and properties of elemental and compound materials, their bonding and band structure, intrinsic and extrinsic semiconducting properties, and various device applications. Letter grading.
121L. Materials Science of Semiconductors Laboratory, (2) Lecture, 30 minutes; discussion, 30 minutes; laboratory, two hours; outside study, three hours. Enrollment required: course 121. Experiments conducted on materials characterization, including measurements of contact resistance, dielectric constant, and thin film biaxial modulus and CTE. Letter grading.

Mr. Goorsky (W)

122. Principles of Electronic Materials Processing, (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enrollment required: course 104. Description of basic semiconductor materials for device processing; preparation and characterization of silicon, III-V compounds, and films. Discussion of principles of CVD, MOCVD, LPE, and MBE; metals silicon, III-V compounds, and films. Discussion of processing; preparation and characterization of various materials; elastic and plastic deformation, fracture toughness, fatigue, and creep. Letter grading.

Mr. Mian (Not offered 2020-21)

143A. Mechanical Behavior of Materials, (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Required requisites: course 104, Mechanical Engineering 101. Elastic flow of metals under simple and combined loading, strain rate and temperature effects, dislocations, fractures, microstructural effects, mechanical and thermal treatment of steel for engineering applications. Letter grading.

Mr. Goorsky (W)

143L. Mechanical Behavior Laboratory, (2) Laboratory, four hours. Requisites: courses 90L, 143A (may be taken concurrently). Methods of characterizing mechanical behavior of various materials; plastic and elastic deformation, fracture toughness, fatigue, and creep. Letter grading.

Mr. Mian (Not offered 2020-21)

150. Introduction to Polymers, (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Polymerization mechanisms, molecular weight and distribution, chemical structure and bonding, structure crystallinity, and morphology and their effects on properties. Solution, polymerization, spinning, polymeric elastomers, adhesives, fiber forming polymers, polymer polymer processing technology, plasticization. Letter grading.

Mr. Pei (W)


Mr. M.-Y. Yang (Sp)

160. Introduction to Ceramics and Glasses, (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Required requisites: courses 104, 130. Introduction to ceramics and glasses being used as important materials of engineering, processing techniques, and unique properties. Examples of design and control of properties for certain specific applications in engineering. Letter grading.

Mr. Dunn (F)

161. Processing of Ceramics and Glasses, (4) Lecture, four hours; discussion, one hour. Required course: 104. Study of processes used in fabrication of ceramics and glasses for structural applications, optics, and electronics. Processing operations, including modern techniques of powder synthesis, green-glass fabrication, laser-microstructure properties relations in ceramics. Fracture analysis and design with ceramics. Letter grading.

Mr. Dunn (Not offered 2020-21)


Mr. J.-Y. Yang (Sp)

140A. Materials Selection and Engineering Design A, (3) Lecture, two hours; laboratory, two hours; outside study, five hours. Required requisites: two courses from 132, 150, 160. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymeric, ceramic, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading.

Mr. J.-M. Yang (Sp)

140B. Materials Selection and Engineering Design B, (3) (Formerly numbered 140.) Lecture, two hours; laboratory, two hours; outside study, five hours. Enrollment required: course 140A. Explicit guidance among myriad materials available for design in engineering. Properties and applications of steels, nonferrous alloys, polymeric, ceramic, and composite materials, coatings. Materials selection, treatment, and serviceability emphasized as part of successful design. Design projects. Letter grading.

Mr. J.-M. Yang (Sp)

141L. Computer Methods and Instrumentation in Materials Science, (2) Laboratory, four hours. Preparation: knowledge of BASIC or C or assembly language. Limited to junior/senior Materials Science and Engineering majors. Interface and control techniques, real-time data acquisition and processing, computer-aided testing. Letter grading.

Mr. Xie (Not offered 2020-21)

CM160. Introduction to Biomaterials, (4) (Same as Bioengineering CM178.) Lecture, three hours; discussion, two hours; outside study, seven hours. Required requisites: course 104, or Chemistry 20A, 20B, and 20L. Engineering materials used in medicine and dentistry for repair and/or restoration of damaged natural tissues. Topics include relationships between material properties, suitability to task, surface chemistry, processing and treatment methods, and biocompatibility. Concurrently scheduled with course CM280. Letter grading.

Mr. Wu (Not offered 2020-21)

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

(Not offered 2020-21)

194. Research Group Seminars: Materials Science and Engineering, (2 to 8) Tutorial, to be arranged. Limited to juniors/seniors. Supervised individual research or investigation under guidance of faculty mentor. Completed form of project required. Occasionally offered for credit with school approval. Individual contract required; enrollment petitions available in Office of Academic and Student Affairs. Letter grading. (F,W,Sp)

Graduate Courses

200. Principles of Materials Science I, (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Required: course 120. Lattice dynamics and thermal properties of materials, electron and positron transport, free electron density, ionization, and quantized free electron theory, electrons in a periodic potential, transport in semiconductors, dielectric and magnetic properties of solids. Letter grading.

Mr. J.-Y. Yang (F)

201. Principles of Materials Science II, (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Required: course 131. Kinetics of diffusional transformations in solids. Precipitation in specific topics include electrochemical reactions on metals and semiconductors, electrodepositio n, electrowet deposition, electro synthesis, fuel cells, aqueous and non-aqueous batteries, solid-state electrochemistry. May be concurrently scheduled with course CM290. Letter grading.

202. Thermodynamics of Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 110 and 110A. Theory of diffractio of waves (X-rays, electrons, and neutrons) in crystalline and noncrystalline materials. Long- and short-range order in crystals, structural effects of plastic deformation, solid–liquid transformation, rearrangement of atoms in liquids and amorphous solids. Letter grading. Mr. Goorsky (W, even years)


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 material science and structure of rock art, wall paintings (including painted surfaces on cement and composite decorative architectural surfaces), and mosaics. Archaeological and ethnographic context, technological and aesthetic aspects, and preservation techniques. Letter grading. Ms. Kakoulli (F)


221. Science of Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisite: course 143A. Introduction to physical, chemical, and electrical properties of materials and semiconductor devices. Topics include: band structure, carrier statistics, energy band model, solid-state physics, bandgap, group theory, conduction, and valence bands. Letter grading. Mr. Goorsky (W)

222. Growth and Processing of Electronic Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: courses 120, 130, 131. Thermodynamics and kinetics that affect semiconductor growth and device processing. Particular emphasis on fundamentals of growth (bulk and epitaxial), heteroepitaxy, implantation, oxidation, electrical, and optical properties of glass and relationship to structure. Letter grading. Mr. Goorsky (W)

223. Materials Science of Thin Films. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Examination of physics behavior of thin films and deposition technology, including experimental parameters. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading. Mr. Goorsky (W)

224. Deposition Technologies and Their Applications. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Examination of physics behavior of thin films and deposition technology, including experimental parameters. Topics include film deposition, interfacial properties, stress and strain, electromigration, phase changes and kinetics, reliability. Letter grading. Mr. Goorsky (W)


226. Si-CMOS Technology: Selected Topics in Materials Science. (4) Lecture, three hours; discussion, one hour; outside study, eight hours. Recommended preparation: Electrical Engineering 252A. Requisites: courses 130, 131, 200, 221, 222. Selected topics in materials science from modern Si-CMOS technology, including technological challenges in high-k metallic gate stacks, strained Si-FETs, SOI and three-dimensional FETs, source/drain engineering, including transiently-enhanced diffusion, nonvolatile memory, and metallization for ohmic contacts. Letter grading. Mr. Xie

243A. Fracture of Structural Materials. (4) Lecture, four hours; laboratory, two hours; outside study, four hours. Requisite: course 143A. Engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture. Fracture mechanics, fracture models, fracture 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 concepts. Letter grading. Mr. J.-M. Yang (W, even 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 crystalline solids, including atomic bonding and structure, atomic-scale defects, microstructural features, residual stresses, temperature, stress-strain rate, size, and surface conditions. Letter grading. Mr. Dunn (W)

246B. Structure and Properties of Glass. (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 photochromism. Magnetic ceramics. Infrared, optical, and ultraviolet transmission. Unique application of ceramics. Letter grading. Mr. Dunn (Sp, even years)

247. Nanoscale Materials: Challenges and Opportunities. (4) Lecture, four hours; discussion, eight hours; laboratory, four hours. Preparation: prerequisite courses of up-to-date subjects in novel materials and their potential applications, including nanoscale materials and biomaterials. Letter grading. Ms. Huang (W)

248. Materials and Physics of Solar Cells. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Comprehensive introduction to materials and photovoltaic cells, covering basic physics of semiconductors in photovoltaic devices, physical properties of solar cell operation, characteristics and
design of common types of solar cells, and approaches to increasing solar cell efficiency. Recent progress in solar cells, such as organic solar cell, thin-film solar cells, and multiple junction solar cells provided to increase student knowledge. Tour of research laboratory included. Letter grading.

Mr. Y. Yang (Sp)


251. Chemistry of Soft Materials. (4) Lecture, four hours. Introduction to organic soft materials, including essential basic organic chemistry and polymer chemistry. Topics include three main categories of soft materials: molecular syntheses, 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 organic electronic materials with emphasis on materials chemistry and processing. Topics include conjugated polymers; heavily doped, highly conducting polymers; applications as processible metals and in various electrical, optical, and electrochemical 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)

253. Bioinspired Materials. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Broad overview of most recent advances in bioinspired materials and biomaterials, covering natural materials, biomimicry, and bioinspired artificial materials, with emphasis on synthesis, processing, hierarchical design, and assembly from nano- to macro-scale, properties and characterizations, and real-life applications. Letter grading.

261. Risk Analysis for Engineers and Scientists. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Topics include definition and fundamentals of risk, sociotechnical systems, risk assessment and risk management, perception and reality of risk, risk-informed decision-making, domains of application (safety, health, security, economy, environment), principal modes 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 algorithms for risk calculation and identification of risk drivers, simulation approach to risk modeling, uncertainty analysis, examples of risk assessment of engineered systems (e.g., space and aviation, nuclear power, petro-chemical plants), other applications (risk of medical procedures, financial risk, natural hazards risk). Letter grading.

CM263. Electrochemical Processes. (4) Same as Chemical Engineering CM214). Lecture, four hours; discussion, one hour; outside study, seven hours. Requisites: course 130 (or Mechanical and Aerospace Engineering 105A), Chemical Engineering 102B. Fundamentals of electrochemistry and engineering applications to industrial electrochemical processes. Primary emphasis on fundamental approach to electrochemical processes. Specific topics include electrochemical reactions on metal and semiconductor surfaces, electrodissolution, electroless deposition, electrosynthesis, fuel cells, aqueous and non-aqueous batteries, solid-state electronics will be concordantly scheduled with course CM163. Letter grading.

270. Computer Simulations of Materials. (4) Lecture, discussion, one hour; 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; basic physical ideas and learning to design, run, and analyze computer simulations of materials. Use of examples from current literature to show these methods can be used to study interesting phenomena in materials science. Hands-on computer experiments. Letter grading. Mr. Marian (F)

271. Electronic Structure of Materials. (4) Lecture, four hours; outside study, eight hours. Preparation: basic quantum mechanics. Recommended requisite: course 200. Introduction to modern first-principles electronic structure calculations for various types of modern materials. Properties of electrons and interatomic bonding in molecules, crystals, and liquids, with emphasis on practical methods for solving Schrödinger equation 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 (F)

272. Theory of Nanomaterials. (4) Lecture, four hours; outside study, eight hours. Strongly recommended requisite: course 200. Introduction to properties and applications of nanoscale materials, with emphasis on understanding of basic principles that distinguish nanostructures (with feature size below 100 nm) from more common microstructured materials. Explanation of new phenomena that emerge only in very small systems, using simple concepts from quantum mechanics and thermodynamics. Topics include structure and electronic properties of quantum dots, wires, nanotubes, and multilayers, self-assembly in liquid solutions, mechanical properties of nanostructured metamaterials, electronic properties, spin-based electronics, and proposed realizations of quantum computing. Discussion of current and future directions of this rapidly growing field using examples from modern scientific literature. Letter grading. Mr. 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 2020-21)

282. Exploration of Advanced Topics in Materials Science and Engineering. (2) Lecture, one hour; discussion, one hour; outside study, four hours. Researchers from leading research institutions around 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 (Sp)

297B. Composites Manufacturing. (4) Same as Mechanical and Aerospace Engineering M297C.) Lecture, four hours; outside study, eight hours. Requisites: course 151, Mechanical and Aerospace Engineering 166C. Matrix materials, fibers, fiber preforms, elements of processing, autoclave/compression molding, filament winding, pultrusion, resin transfer molding, automation, material removal and assembly, and metal and ceramic matrix composites, quality assurance. Letter grading.

298. Seminar: Engineering. (2 to 4) Seminar, to be arranged. Limited to graduate materials science and engineering students. Seminars may be organized in advanced technical fields. If appropriate, field trips may be arranged by topic change. Letter grading.

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

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

597A. Preparation for MS Comprehensive Examination. (2 to 12) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Preparation for comprehensive examination, including preliminary research on dissertation. S/U grading.

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

597C. Preparation for PhD Oral Qualifying Examination. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Supervised independent research for MS candidates, including thesis prospectus. S/U grading.


599. Research for and Preparation of PhD Dissertation. (2 to 16) Tutorial, to be arranged. Limited to graduate materials science and engineering students. Usually taken after students have been advanced to candidacy. S/U grading.
Mechanical and Aerospace Engineering

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Department e-mail
Department website

Timothy S. Fisher, Ph.D., Chair
Eric Pei-Yu Chiou, Ph.D., Vice Chair
Jeffrey D. Eldredge, Ph.D., Vice Chair
Chang-Jin (CJ) Kim, Ph.D., Vice Chair

Professors
Mohamed A. Abdou, Ph.D.
Robert N. Candler, Ph.D.
Gregory P. Carman, Ph.D. (Ben Rich-Lockheed Martin Chair in Advanced Aerospace Technologies)
Yong Chen, Ph.D.
Eric Pei-Yu Chiou, 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.
Vijay Gupta, Ph.D.
Dennis W. Hong, Ph.D.
Tetsuya Iwasaki, Ph.D.
Y. Sungtaek Ju, Ph.D.
Ann R. Karagianzian, Ph.D.
H. Pirouz Kavehpour, Ph.D.
Chang-Jin (CJ) Kim, Ph.D. (Volgenau Endowed Professor of Engineering)
Adrienne G. Lavine, Ph.D.
Xiaochn Li, Ph.D. (Raytheon Company Professor of Manufacturing Engineering)
Kuo-Nan Liou, Ph.D.
Ajit K. Mal, 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.
Richard E. Wirz, Ph.D.
Xiaolin Zhong, Ph.D.

Professors Emeriti
Oddvar O. Bendiksen, Ph.D.
Ivan Catton, Ph.D. (Research Professor)
Peretz P. Friedmann, Sc.D.
Nasr M. Ghoniem, Ph.D.
James S. Gibson, Ph.D.
Chih-Ming Ho, Ph.D. (Ben Rich-Lockheed Martin Professor Emeritus of Aeronautics)
Robert E. Kelly, Sc.D.
J. John Kim, Ph.D. (Rockwell Collins Professor Emeritus of Engineering)
Anthony F. Mills, Ph.D.
D. Lewis Mingori, Ph.D.
Peter A. Monkiewitz, 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
Elisa Franco, Ph.D.
Jonathan B. Hopkins, Ph.D.
Yongjie Hu, Ph.D.
Jaime Marian, Ph.D.
Veronica J. Santos, Ph.D.
Kunihiko (Sam) Taira, Ph.D.

Assistant Professors
Tyler R. Clites, Ph.D.
Artur Davoyan, Ph.D.
M. Khalid Javed, Ph.D.
Lihua Jin, Ph.D.
Yen-Chih (Neil) Lin, Ph.D.
Raymond M. Spearrin, Ph.D.
Xiaoyu (Rayne) Zheng, Ph.D.

Lecturers
Ravneesh C. Amar, Ph.D.
Amiya K. Chatterjee, Ph.D.
Robert J. Kinsey, Ph.D.
Darnian M. Toohey, M.S.

Adjunct Professors
Portono S. Ayasyawmy, Ph.D.
Dan M. Goebel, Ph.D.
Vinay K. Goyal, Ph.D.
Leslie M. Lackman, Ph.D.
Christopher S. Lynch, Ph.D.
Wilbur 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, nanoelectromechnical 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.

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 150B, C150R, 154S, 161A, 161B, 161C; Physics 1A, 1B, 1C, 4AL, 4BL.

**The Major**

Required: Mechanical and Aerospace Engineering 1, 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 (12 units) selected 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, C150R, 154S, 161A, 161B, 161C (unless taken as a required course), or from 94, 131A, C131G, 133A, 135, 136, C137, C138, CM140, 150C, C150G, 154B, 155, C156B, 162A, C162B, C163A, C163B, C163C, 166C, M168, 169A, 171B, 172, 174, C175A, 181A, 182B, 182C, 183A, M183B, C183C, 185, C186, C187L.

For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or the GE Requirement web page.

**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, 4AL, 4BL.

**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), C131G, 133A (unless taken as a required course), 135, 136, C137, C138, CM140, 150A, 150B, 150C, C150G, C150P, C150R, 154B, 154S, 155, C156B, 157A, 161A through 161C, C162B, C163A, C163B, C163C, 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, 185, C186, C187L.
For information on UC, school, and general education requirements, see Requirements for B.S. Degrees on page 22 or the GE Requirement web page.

Graduate Study
For information on graduate admission, see Graduate Programs on page 26.

The following introductory information is based on 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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 598 courses involving work on the thesis. In the comprehensive examination plan, no units of 500-series courses may be applied toward the minimum course requirement. Courses taken before the award of the bachelor’s degree may not be applied toward a graduate degree at UCLA. The courses should be selected so that the breadth requirements and the requirements at the graduate level are met. The breadth requirements are only applicable to students who do not have a B.S. degree from an ABET-accredited aerospace or mechanical engineering program.

Undergraduate Courses. No lower-division courses may be applied toward graduate degrees. In addition, the following upper-division courses are not applicable toward graduate degrees: Chemical Engineering 102A, 199, Civil and Environmental Engineering 108, 199, Computer Science M152A, M152B, M171L, 199, Electrical and Computer Engineering 100, 101A, 102, 110L, M116L, M133A, M171L, 199, Materials Science and Engineering 110, 120, 130, 131, 131L, 132, 140A, 140B, 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 an oral 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. 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.

Upper-Division Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering M168, 174, 183A, 185.

Graduate Courses. Students are required to take at least three courses from the following: Mechanical and Aerospace Engineering C263A, C263C, 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; micro-nano engineering; 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 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, hypersonic flows, microscale and nanoscale flow phenomena, aeroacoustics, biofluid mechanics, chemically reactive flows, chemical reaction kinetics, numerical methods for computational fluid dynamics (CFD), and experimental methods. The educational program for graduate students provides a strong foundational background in classical incompressible and compressible flows, while providing elective breadth courses in advanced specialty topics such as computational fluid dynamics, microfluidics, biofluid mechanics, hypersonics, reactive flow, fluid stability, turbulence, and experimental methods.

Micro-Nano Engineering

The micro-nano engineering 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 nanofabrica-
tion/microfabrication technologies, molecular fluidic phenomena, nanoscale/microscale material processing, biomolecular signatures, heat transfer at the nanoscale, and system integration. The program is highly interdisciplinary in nature.

**Structural and Solid Mechanics**

The solid mechanics program features theoretical, numerical, and experimental studies, including fracture mechanics and damage tolerance, micromechanics with emphasis on technical applications, wave propagation and nondestructive evaluation, mechanics of composite materials, mechanics of thin films and interfaces, analysis of coupled electro-magneto-thermomechanical material systems, and ferroelectric materials. The structural mechanics program includes structural dynamics with applications to aircraft and spacecraft, fixed-wing and rotary-wing aerelasticity, fluid structure interaction, computational transonic aerelasticity, 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 micro-scale 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. See the department website research tab for details.

**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, solenoids, and electrical power supplies.

**Additive Manufacturing and Metamaterials Laboratory**

Xiaoyu (Rayne) Zheng, Director

The *Additive Manufacturing and Metamaterials Laboratory* performs research on additive manufacturing and material designs for structural and multifunctional devices. It draws principles from mechanics, optics, and materials science to develop the next generation of additive manufacturing (3D printing) processes, material design, and synthesis approaches to create multifunctional materials and all-in-one devices with controlled topologies, compositions, and multiscale features. It also develops methods to leverage artificial intelligence and rapid prototyping techniques to design metamaterials with tailorable mechanical and functional behaviors. These materials can be transferred to a wide array of applications for 3D electronics, structures, robotics, energy storage, and transportation; even biology and health care. The lab houses custom, scalable additive manufacturing capabilities and digital light-processing techniques for a wide range of multimaterials, with feature sizes ranging from tens of nanometers, to tens of centimeters, and above.

**Anatomical Engineering Group**

Tyler R. Clites, Director

The group researches anatometrics, the co-engineering of body and machine in pursuit of synergistic bionic performance. The research combines surgical and mechanical design to codvelop body and machine. The long-term goal of the work is to transform the field of human rehabilitation and augmentation by making anatometrics a fundamental tenet of bionic development.

**Autonomous Vehicle Systems Instrumentation Laboratory (AVSIL)**

Jason L. Speyer, Director

**AVSIL** is a testbed 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 intervehicle modem 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 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 Translational Applications of Nanoscale Multiferroic Systems (TANMS)**
Gregory P. Carman, Director
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 goal is 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
The Chen Research Group studies nanofabrication, nano-scale electronic materials and devices, micro-nano electronic/optical/bio/mechanical systems, and ultrascalar spatial and temporal characterization.

**Collaborative Center for Aerospace Sciences (CCAS)**
Ann R. Karagozian, Director
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 the Air Force Research Laboratory (AFRL/RQR) at Edwards Air Force Base, about 90 miles 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 (CyClab)**
Tetsuya Iwasaki, Director
CyClab investigates the neuronal mechanisms for information processing and learning. It also develops fundamental theories for analysis and design of dynamical feedback systems, with applications to bio-inspired robotic vehicles, assistive devices for human movements, and neurorehabilitation after spinal cord injury.

**Davoyan Research Laboratory (A-Lab)**
Artur Davoyan, Director
The laboratory is focused on nanoscale materials for space and energy applications. Research topics encompass space exploration, device physics, and sustainability.

**Design and Manufacturing Laboratory**
The 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.

**Dynamic Nucleic Acid Systems Laboratory**
Elisa Franco, Director
The Dynamic Nucleic Acid Systems Laboratory develops mathematical models and experimental platforms to build adaptive and dynamic biological devices using DNA, RNA, and proteins. The results have applications in materials science, nanotechnology, and synthetic biology.

**Energy and Propulsion Research Laboratory**
Ann R. Karagozian, Director
The Energy and Propulsion Research Laboratory applies modern diagnostic methods and computational tools to the development of advanced rocket and airbreathing propulsion as well as energy systems. Research involves applications of fundamental fluid mechanics, combustion chemistry, dynamical systems, and optics.

**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-scales.

**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 thermonuclear, thermodynamics, 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 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 governing algebraic quadratic equation, PRS dictates the composition and ratio of a globally optimized drug combination. Based on the PRS platform, 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

H-Lab is focused on understanding and engineering fundamental transport phenomena and new materials for wide applications including energy conversion, storage, aerospace, electronics, thermal management, micro/nano sensors, and biomedical devices. The laboratory uses a variety of experimental and theoretical techniques to investigate nanoscale transport processes and develop device applications, with a particular emphasis on design, chemical synthesis, and manufacturing of advanced materials, ultrafast optical spectroscopy, pulsed electronics, thermal spectral mapping techniques, ab initio calculations, and atomistic modeling.

**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. Spearrin, Director

The Laser Spectroscopy and Gas Dynamics Laboratory conducts research driven by applications in propulsion and energy, with extensions to health and environment. Laboratory 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.

**Living Soft Material Engineering Laboratory (Lin Lab)**
Yen-Chih (Neil) Lin, Director

Lin Lab research looks at developing 3D biological tissues that mimic the geometric structure, mechanical properties, and functionality of human organs. Major research focuses include development of live cell imaging tools, cell mechanics measurements, and tissue manufacturing methods. This research could lead to detailed and complex model tissues for drug screening; and ultimately, artificial organs that could be transplanted into humans.

**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 nondestructive evaluation.

**Materials in Extreme Environments Laboratory (MATRIX)**
Nasr M. Ghoniem, Director

MATRIX 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.

**Sensors and Instrumentation Laboratory**
Robert T. M’Closkey, Director

The Sensors and Instrumentation Laboratory focuses on the design, fabrication, modeling, and testing of microscale sensors, notably coriolis vibratory gyroscopes. The laboratory offers the opportunity to conduct leading-edge analytical and experimental research in state-of-the-art facilities.

**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 laboratory 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 explores physical phenomena unique in submillimeter scale, and utilizes microelectromechanical systems (MEMS) technologies to advance important knowledge and create useful applications. Surface tension is one such phenomenon, which led to cutting-edge discoveries and revolutionary applications, some commercialized. Research themes include electrowetting-on-dielectric (EWOD), electro-dewetting, droplets and bubbles, and superhydrophobic surfaces; and application areas include droplet (digital) microfluidics, micro fuel cells, and drag reduction of liquid flows. Typical research starts with a novel concept, and completes with application devices of commercial implication. The laboratory has various equipment to complement the Nanolab (e.g., fume hood, modular cleanroom, environment chambers, probe stations, microscopes, dicing saw, electroplating setup, and interference lithography); and facilitate drag-reduction research (e.g., water tunnel and molding setup), including a 13-foot motorboat at a local marina.

**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 Heat transfer laboratory is engaged in a broad range of interdisciplinary research projects at the intersection of interfacial and transport phenomena, radiation transfer, material science, and biology for sustainable solar energy conversion; waste heat energy harvesting; electrical energy storage; and energy efficient buildings. The laboratory features state-of-the-art equipment for material synthesis and characterization such as glove boxes and high-temperature furnaces, potentiostats, calorimeters, and thermal conductivity analyzers. It is also equipped with a full set of instru-
ments for optical characterization of solids, liquids, and suspensions from ultraviolet to infrared wavelengths (e.g., spectrometers, lasers, and detection systems). The laboratory also has various instrumented flow loops for rheological and convective heat transfer experiments with complex fluids.

**Multiscale Thermosciences Laboratory (MTSL)**
Y. Sungtaek Ju, Director

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 (NTRG)**
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 laboratory 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**
Eric Pei-Yu Chiou, Director

The Optofluidics Systems Laboratory develops heterogeneously integrated functional devices and systems for biomedical applications. Research areas include integrated photonics and fluids 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**
The 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 nano-phase clusters for applications in thermal insulation, wear resistance, and high-temperature oxidation resistance.

**Plasma and Space Propulsion Laboratory**
Richard E. Wirz, Director

The Plasma and Space Propulsion Laboratory investigates plasmas using a combination of experimental, computational, and theoretical perspectives. Its research is directly inspired by the rapidly emerging field of electric propulsion (EP). Other applications of its work include microplasmas, plasma processing, and fusion.

**Robotics and Mechanisms Laboratory (RoMeLa)**
Dennis W. Hong, Director

RoMeLa is a facility for robotics research and education with an emphasis on studying humanoid robots and novel mobile robot locomotion strategies. Research is in the areas of robot locomotion and manipulation, soft actuators, platform design, kinematics and mechanisms, and autonomous systems. RoMeLa is active in research-based international robotics competitions, winning numerous prizes including third place in the DARPA Urban Challenge. The laboratory also took first place in the RoboCup international autonomous robot soccer competition (kid-size and adult-size humanoid divisions), and was world champion five times in a row. It also brought the prestigious Louis Vuitton Cup Best Humanoid award to the U.S. for the first time, and most recently was one of six Track A teams chosen to participate in the DARPA Robotics Challenge disaster response robot competition.

**Scifacturing Laboratory**
Xiaochun Li, Director

The Scifacturing Laboratory furnishes a creative, interdisciplinary platform for science-driven manufacturing (scifacturing) as the next level of manufacturing. It seeks to enable application of physics and chemistry to empower breakthroughs in manufacturing. The laboratory links molecular, nano-, and micro-scale knowledge to scalable processes/systems in manufacturing and materials processing. Current focus areas include scale-up nanomanufacturing, solidification nanoprocessing of super-materials with dense nanoparticles, structurally integrated micro- and nano-systems (especially sensors and actuators) for manufacturing, clean energy and biomedical manufacturing, meso/micro 3D printing, and laser materials processing.

**Simulations of Flow Physics and Acoustics Laboratory (SOFIA)**
Jeffrey D. Eldredge, Director

The 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; microparticle manipulation by visous streaming; the fluid dynamics of biological and biomechanically inspired locomotion; interactions of fluid flows with flexible surfaces; transitional and turbulent hypersonic boundary layer flows; vortex estimation techniques for autonomous control of formation flight; and new computational tools for simulation of biomedical flows.

**Smart Grid Energy Research Center (SMERC)**
Rajit Gadh, Director

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 furnishes thought leadership through its ESmart Consortium between utilities, government, policy makers, technology providers, electric vehicle manufacturers, energy technology companies, Department of Energy research laboratories, and universities, so as to collectively work on envisioning, planning, and executing the smart grid of the future. This grid will enable integration of renewable energy sources. It will also reduce losses; improve efficiencies; increase grid flexibility; allow for integration of electric and autonomous vehicles; reduce power outages; allow for competitive energy pricing; and overall become more responsive to market, consumer, and societal needs. SMERC is currently working on electric vehicle integration (C2V 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 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; microparticle manipulation by visous streaming; the fluid dynamics of biological and biomechanically inspired locomotion; interactions of fluid flows with flexible surfaces; transitional and turbulent hypersonic boundary layer flows; vortex estimation techniques for autonomous control of formation flight; and new computational tools for simulation of biomedical flows.

**Computational Fluid Dynamics Laboratory (Taira Lab)**
Kunihiko (Sam) Taira, Director
The Computational Fluid Dynamics Laboratory studies a variety of fluid mechanics problems with research interests in the areas of computational fluid dynamics, flow control, data science, network theory, and unsteady aerodynamics. The studies leverage numerical simulations performed on high-performance computers.

**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 servo-hydraulic biaxial test frame, and polishing and imaging equipment for microstructural characterization; for measurement and control study of thin film interface strength.

**Faculty Areas of Thesis Guidance**

**Professors**

- Mohamad A. Abdou, Ph.D. (U. Wisconsin, 1973) Fusion, nuclear, and mechanical engineering design, testing, and system analysis, thermomechanics; thermal hydraulics; fluid dynamics; heat, and mass transfer in the presence of magnetic fields (MHD flows); neutronics; radiation transport; plasma-material interactions; blanketed and high heat flux components; experiments, modeling and analysis
- Robert N. Candler, Ph.D. (Stanford, 2006) MEMS/NEMS free-electron lasers, miniature medical devices, nanoscale magnetic structures and devices, additive manufacturing, fundamental limits of micro- and nanodevices
- 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
- Vijay K. Dhir, Ph.D. (U. Kentucky, 1972) Two-phase heat transfer, boiling and condensation, thermal hydrualics of nuclear reactors, microgravity heat transfer, soil remediation, high-power density electronic cooling
- Jeffrey D. Eldredge, Ph.D. (Caltech, 2005) Numerical simulations of fluid dynamics, bio-inspired locomotion in fluids, transition and turbulence of high-speed flows, aerodynamically generated sound, vorticity-based numerical methods, simulations of biomedial flows
- Timothy S. Fisher, Ph.D. (Cornell, 1998) Heat and mass transfer, interfacial transport, nanomaterial synthesis, nano-/micro-device fabrication, non-equilibrium thermodynamics, substitution, combustion, 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
- Rajit Gadh, Ph.D. (Carnegie Mellon, 1991) Smart grid, electric vehicle and grid integration, microgrid, distributed energy resources, solar- and renewable-grid integration, demand response, autonomous electric vehicle, machine learning from transportation data, radio frequency identification (RFID), Internet of things
- Naser M. Ghiomeh, 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); multi-scale modeling; physics and mechanics of material defects; fusion energy; materials for space propulsion
- 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
- Dennis W. Hong, Ph.D. (Purdue, 2002) Analysis and stabilization of contact force solution space for multilegged mobile robots

**Dynamical systems, robust and optimal control, 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-water nexus, MEMS and nanotechnology
- Ann R. Karagopian, Ph.D. (Caltech, 1982) Fluid mechanics and combustion with applications to airbreathing, 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 bioreactors, biofluids coating flows and physics of contact line phenomena, complex fluids, non-isothermal flows, energy systems and energy storage
- Chang-Jin (CJ) Ph.D. (UC Berkeley, 1991) Microsystems, microelectro-mechanical systems (MEMS), micro/nano devices and fabrication technologies, microfluidics especially involving surface tension and droplets
- 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
- Robert T. M’Closkey, Ph.D. (Caltech, 1995) Nonlinear control theory and design with application to mechanical and aerospace systems, real-time implementation
- 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 assessment, analysis
- Jayathi Y. Murthy, Ph.D. (U. Minnesota, 1984) Nanoscale heat transfer, computational fluid dynamics, simulation of fluid flow and heat transfer for industrial applications, sub-micron thermal transport, multiscale multiphysics simulations and uncertainty quantifications
- Laurent G. Plion, Ph.D. (Purdue, 2002) Interfacial and transport phenomena, radiation transfer, materials synthesis, multi-phase flow, heterogeneous media
- Jacob Rosen, Ph.D. (Tel Aviv U., Israel, 1997) Natural integration of a human arm/powered exoskeleton system
- Jason L. Speyer, Ph.D. (Harvard, 1968) Stochastic and deterministic optimal control and estimation with application to aerospace systems; guidance, flight control, and flight mechanics
- Tsu-Chin Tiao, Ph.D. (UC Berkeley, 1988) Mechatronics and control with applications in mechanical systems, manufacturing, vehicles, medical robots, and energy
- Xiaolin Zhong, Ph.D. (Stanford, 1991) Computational fluid dynamics, advanced high-order CFD methods, hypersonic flow, numerical simulation of transient hypersonic flow with nonequilibrium real-gas effects, instability and laminar-turbulent transition of hypersonic boundary layers

**Professors Emeriti**

- Oddvar O. Bendiksen, Ph.D. (UCLA, 1980) Classical and computational aeroelasticity, structural dynamics and unsteady aerodynamics
- Ivan Catton, Ph.D. (UCLA, 1966) Heat transfer and fluid mechanics, transport phenomena in porous media, nucleosics heat transfer and thermal energy storage, natural and forced convection, thermal-hydraulic stability, turbulence
- 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
- Chih-Ming Ho, Ph.D. (Johns Hopkins, 1974) Molecular fluidic phenomena, microelectromechanical systems (MEMS), biotechnology, biomolecular sensor arrays, control of cellular complex systems, rapid search of combinatorial medicine
- 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
- Anthony F. Mills, Ph.D. (UC Berkeley, 1965) Convective heat and mass transfer, condensation heat transfer, turbulent flows, ablation and transpiration cooling, perforated plate heat exchangers
- D. Lewis Mingori, Ph.D. (Stanford, 1966) Dynamics and control, stability theory, non-linear methods, applications to space and ground vehicles
Peter A. Monkewitz, Ph.D. (ETH Zürich, Switzerland, 1977)
Fluid mechanics, internal acoustics and noise produced by turbulent jets

Philip F. O’Brien, M.S. (UCLA, 1949)
Industrial engineering, environmental design, thermal and luminous engineering systems

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

Owen I. Smith, Ph.D. (UC Berkeley, 1977)
Combustion and combustion-generated air pollutants, hydrodynamics and chemical kinetics of combustion systems, semiconductor chemical vapor deposition

Richard Stern, Ph.D. (UCLA, 1964)
Experimentation in noise control, physical acoustics, engineering acoustics, medical acoustics

Russell A. Westmann, Ph.D. (UC Berkeley, 1962)
Mechanics of solid bodies, fracture mechanics, adhesive mechanics, composite materials, theoretical soil mechanics, mixed boundary value problems

Daniel C.H. Yang, Ph.D. (Rutgers, 1982)
Robotics and mechanisms; CAD/CAM systems, computer-controlled machines

Associate Professors

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 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

Veronica J. Santos, Ph.D. (Cornell, 2007)
Grasp and manipulation, hand biomechanics, haptic, human-machine systems, machine learning, machine perception, neural control of movement, prosthetics, robotics, stochastics modeling, tactile sensor

Kunihiko (Sam) Taara, Ph.D. (Caltech, 2008)
Development of computational fluid dynamics that incorporate unsteady aerodynamics, low flow, and control network theory

Richard E. Wirz, Ph.D. (Caltech, 2005)
Electric propulsion (ion, Hall, electrospays, cathodes); micro-electric propulsion; partially ionized plasma discharges; miniature plasma devices; spacecraft/space mission design; wind energy; solar thermal energy; thermal energy storage

Assistant Professors

Tyler R. Citles, Ph.D. (MIT, 2018; joint program certificate, Harvard Medical-MIT, 2018)
Biomechanics system to rehabilitate and augment human function; movement biomechanics; neural interfacing and control; advancements in orthopaedic and plastic surgery

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 machine design; novel micro- and nano-fabricated devices; MEMS

Yongjie Hu, Ph.D. (Harvard, 2011)
Heat transfer and electron transport in nanostructures; interfaces and packaging; thermal, electronic, optoelectronic, and thermoelectric devices and 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 manufacturing

Liwu Jin, Ph.D. (Harvard, 2014)
Mechanics of soft materials; continuum mechanics and applications in technologies: additive manufacturing, soft robotics and stretchable electronics, nanomechanics, and multiscale modeling

Yen-Chih (Neil) Lin, Ph.D. (Cornell, 2016)
Micro-nano sciences: tissue engineering, developments of advanced optical microscopy, mechanical materials

Raymond M. Spearin, 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

Ravnesh C. Amar, Ph.D. (UCLA, 1974)
Heat transfer and thermal science

Aмиka K. Chatterjee, Ph.D. (UCLA, 1976)
Elastic wave propagation and penetration dynamics

Modeling, simulation, and analysis of spacecraft dynamics and pointing control systems; nonlinear dynamics of spinning bodies; concurrent engineering methods for space mission conceptual design

Damian M. Toohey, M.S. (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

Portono S. Ayyaswamy, Ph.D. (UCLA, 1971)
Multiphase, multiscale flow and heat/mass transfer

Dan M. Goebel, Ph.D. (UCLA, 1981)
Hollow cathode, magnetic-multipole ion sources for neutral beam injection

Vinay K. Goyal, Ph.D. (Virginia Tech, 2002)
Analytical modeling of the mechanics of nucleation and growth of cracks, mechanics of composite materials, failure theories, finite elements of elastomeric and metallic materials, fatigue and fracture, non-destructive evaluation, computational mechanics, shape memory alloys, additive manufacturing, advanced mechanisms

Leslie M. Lackman, Ph.D. (UC Berkeley, 1967)
Structural analysis and design, composite structures, engineering management

Christopher S. Lynch, Ph.D. (U. Santa Barbara, 1992)
Field coupled materials, constitutive behavior, thermo-electro-mechanical properties, sensors and actuator applications, fracture mechanics and failure analysis

William 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. Eldredge (F)

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


Mr. Tsiaglou (F, W, S)


94. Introduction to Computer-Aided Design and Drafting. (4) Lecture, two hours; laboratory, four hours. Fundamentals of computer graphics and two- and three-dimensional modeling on computer-aided design and drafting systems. Students use one or more online computer systems to design and display various objects. Letter grading.

Mr. Li (W, S)

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

120 / Mechanical and Aerospace Engineering

problems. Stresses in thin-walled pressure vessels and in circular cylinders under torsion. Letter grading.

Mr. Mal (F,W,Sp)


Ms. Santos (F,W,Sp)


Mr. Kavehpour (F,W,Sp)

105A. Introduction to Engineering Thermodynamics. (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. Introduction to modeling of physical systems, with examples of mechanical, fluid, thermal, and electrical systems. Description of these systems with coverage of impulse response, convolution, frequency response, first- and second-order systems transient response analysis, and numerical solution. Nonlinear differential equation descriptions with discussion of equilibrium solutions, small signal linearization, large signal response, and computer representation of response of interconnected systems. Hands-on experiments reinforce lecture material. Letter grading.

Mr. M'Closkey, Mr. Tsao (F,W,Sp)


Ms. Lavine (F,W,Sp)

C131G. Microscopic Energy Transport. (4) Lecture, four hours, outside study, eight hours. Requisite: course 105D. Exploration of basic principles of transport of energy in nature and fabricated structures by three carriers: electrons, phonons, and molecules. Study of statistical properties of heat carriers, common and facts of heat flow, conduction and convection, and transport of heat carriers, derivation of classical laws from microscopic transport equations, and deviation from classical laws at small scale. Concurrently scheduled with course C235. Letter grading.

Mr. Gupta (W)


Mr. Ju (Not offered 2020-21)

CM140. Introduction to Biomechanics. (4) Same as Bioengineering CM140) Lecture, four hours, discussion, two hours; outside study, six hours. Requi- sites: courses 101, 102, and 156A or 166A. Introduction to mechanical functions of human body: skeletal muscle, locomotion and control. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM240. Letter grading.

Mr. Gupta (W)

150B. Aerodynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requi- sites: courses 103, 150A, 150B. Fundamentals of po- tential flow theory. Incompressible flow around thin airfoils (lift and moment coefficients) and wings (lift, induced drag). Gas dynamics: oblique shocks, normal shock reflections, expansion fans, orthogonality of above and below potential flow. Letter grading.

Mr. Eldredge, Ms. Karagopian (F,W)


Mr. Pimentell (W)

150D. Fluid Dynamics of Biological Systems. (4) Lecture, four hours; outside study, eight hours. Requis- ites: course 103. Mechanics of aquatic locomotion; Introduction with applications of Newtonian mechanics, fluid mechanics principles of mechanisms to flow of compressible and incompressible fluids. Letter grading.

Mr. Abdou (Not offered 2020-21)

136. Energy and Environment. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course 105A. Global en- ergy use and supply, renewable power generation, fossil fuel and nuclear power plants, renewable energy such as hydropower, biomass, geothermal, solar, wind, and ocean, fuel cells, transportation, energy conservation, air and water pollution, global warming. Letter grading.

Mr. Pilon (Sp)

C137. Design and Analysis of Smart Grids. (4) Lecture, four hours; outside study, eight hours. De- mand response; transactive/price-based load con- trol; smart grid design and operation profile; advanced metering infrastructure; renewable energy in-tegration; solar and wind generation interconnection and control; microgrids; grid stability; energy storage and electric vehicles; monitoring; grid operation and control; wireless communications; sensors, communications, and compting; wireless, wireline, and powerline communications for smart grids; grid modeling, stability, and control; frequency and voltage regulation; ancillary services; wide-area situational awareness, phase measurements; analytical methods and tools for monitoring and control. Concurrently scheduled with course C235. Letter grading.

Mr. Gadkhi (F)

C138. Introduction to Statistical Thermody- namics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 105A, 105D. Introduction to basic concepts and tools of statistical thermody- namics. Abstract concepts of entropy, temperature, and chemical potential are explained by developing these concepts from ground up using only mechan- ical and statistical principles. Exploration of equilib- rium properties of thermodynamic systems and asso- ciated distributions. Provides sound foundation for further studies in transport phenomena, plasma, chemical kinetic, biophysical science, and technology, and other related subjects. Concurrently scheduled with course C238. Letter grading.

Mr. Ju (Not offered 2020-21)

154A. Preliminary Design of Aircraft. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 154S. Classi- cal preliminary design of aircraft, including weight estimation, performance and stability, and control consideration. Term assignment consists of prelimi- nary design of low-speed aircraft. Letter grading.

Mr. Karagopian, Mr. Wizr (W)


1545. 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. Wizr (W)

155. Intermediate Dynamics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Requisite: course 102. Axioms of Newtonian mechanics, generalized coordinates, equations of motion, variational principles; central force motion; kine- matics and dynamics of rigid bodies. Euler equations, motion of rotating bodies, oscillatory motion, normal coordinates, orthogonality relations. Letter grading.

Mr. Gibson (Not offered 2020-21)


Mr. Malay (F,W,Sp)
C156B. Mechanical Design for Power Transmission. (4) Lecture, four hours; outside study, six hours. Required: course 156A or 166A. Material selection in mechanical design. Load and stress analysis. Deflection and stiffness. Failure due to static loading. Design for safety and reliability. Applications of failure prevention in design of power transmission shafting. Design project involving computer-aided design (CAD) and finite element analysis (FEA) modeling. Concurrently scheduled with course C149A. Letter grading. Mr. Ghoniem (Sp)

157. Basic Mechanical and Aerospace Engineering Laboratory. (4) Laboratory, eight hours; outside study, four hours. Requisites: courses 101, 102, 103, 105A. Electrical Engineering 100. Methods of measurement of basic quantities and performance of basic experiments in fluid mechanics, structures, and thermodynamics. Primary sensors, transducers, recording equipment, signal processing, and data analysis. Letter grading. Mr. Ju (F, W, Sp)

157A. Aerospace Design Laboratory. (4) Lecture, two hours; laboratory, six hours; outside study, four hours. Lectures: dynamics, aero, 157A. Recommended: 150B, 1510R. Experimental illustration of important physical phenomena in area of fluid mechanics/aerodynamics, as well as hands-on experience with various experimental programs and use of modern experimental tools and techniques in field. Letter grading. Mr. Spearin (Sp)

161A. Introduction to Astronautics. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended preparation: course 102. Recommended: course 128. Spaceflight, including two-body and three-body problem, Kepler laws, and Keplerian orbits. Orbit and transfer maneuvers, patched conic/perturbation theory, low-thrust trajectories, spacecraft pointing, and spacecraft attitude control. Space mission design, space environment, rendezvous, entry, and landing. Letter grading. Mr. Dinwiddie (W)

161B. Introduction to Space Technology. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Recommended preparation: courses 102, 161A. Spacecraft systems and dynamics, including spacecraft power, instruments, communications, structures, materials, thermal control, and attitude/orbit determination and control. Space mission design, launch vehicles/considerations, space propulsion. Letter grading. Mr. Wisz (Sp)

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 in groups of three or four, with each student responsible primarily for one subsystem and for integration with whole. Letter grading. Mr. Wisz (Sp)


C162B. Compliant Mechanism Design. (4) Lecture, four hours; outside study, eight hours. Requisite: linear algebra. Advanced compliant mechanism synthesis and optimization techniques. Bifurcations, modeling techniques, and optimization tools. Fundamentals of flexible constraint theory, principles of constraint-based design, projective geometry, screw theory kinematics, and freedom and constraint topologies. Applications: precision motion stages, general purpose flexure bearings, microstructural architectures, MEMs, optical mounts, and nanoscale positioning systems. Hands-on exercises involving personal computer-aided design and FEA simulations, and term project. Concurrently scheduled with course C149A. Letter grading. Mr. Closkey (F, W, Sp)

162D. Mechanical Engineering Design I. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisites: courses 94, 156A (or 183A or M183B), 162A (or 171A). Limited to seniors. First of two mechanical engineering capstone design courses. Course content is designed to provide students with knowledge and experience in product design and manufacture, design of thermal systems, mechatronics, mechanical systems, and mechanical components. Students work in teams to begin their two-term design project. Describ design concepts, analysis, including CAD analysis, mechatronics, and conceptual design for team project. Letter grading. Mr. Tsao (W)

162E. Mechanical Engineering Design II. (4) Lecture, two hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 162D. Concurrently scheduled with course C296A. Letter grading. Mr. Tsao (Sp)

170. Control System Design Laboratory. (4) Lecture, four hours; laboratory, four hours; outside study, six hours. Enforced requisite: course 171A. Introduction to loop shaping controller design with application to laboratory electromechanical systems. Power spectrum models of noise and disturbances, and performance trade-offs imposed by conflicting requirements. Constraints on sensitivity function and complementary sensitivity function imposed by non-minimum phase plants. Lecture topics supported by weekly hands-on laboratory work. Letter grading. Mr. 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. Enforced requisite: courses 82, 107. Probability spaces, random variables, distributions, functions of random variables, models of failure of components, reliability, redundancy, complex systems, stress-strength models, fault trees, quality control and reliability, and 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 processes and processes, expectation, conditional expectation, Gauss/Markov sequences, and random variables. Study with applications. Concurrently scheduled with course C271A. Letter grading. Mr. Sprey (R)

181A. Complex Analysis and Integral Transforms. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course 82. Complex variables, analytic functions, conformal mapping, contour integrals, singularities, residues, Cauchy integrals, Laplace transform; properties of Fourier transform; properties, convolution, FFT, applications in dynamics, vibrations, structures, and heat conduction. Letter grading. Mr. M’Closkey (Not offered 2020-21)


182C. Numerical Methods for Engineering Applications. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisite: course 82. Numerical methods for solving partial differential equations, including the finite element and finite difference methods, numerical quadrature, and finite difference approximations. Numerical solution of initial and boundary value problems for ordinary and partial differential equations. Letter grading. Mr. Zhong (F)

C163C. Rapid Prototyping and Manufacturing. (4) Lecture, four hours; laboratory, two hours; outside study, six hours. Enforced requisite: course 183A. Rapid prototyping (RP), solid freeform fabrication, or additive manufacturing has emerged as popular manufacturing technology to accelerate product development 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 part shape or 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 been extended into meso- and nanoscale to produce three-dimensional functional miniature components. Concurrently scheduled with course 228L. Letter grading. Mr. Li (W)

185. Introduction to Radio Frequency Identification and Its Application in Manufacturing and Supply Chain. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: course M20 or Civil Engineering M20 or Computer Science 31. Manufacturing today requires assembling of individual components into assembled products. Components, products, and even the use, maintenance, and recycling of such products. Radio frequency identification (RFID) chips installed on components, subassemblies, and assemblies of products enable accurate identification when they move and transform through manufacturing supply chain. RFID tags have memory and small CPU that allows information about product status to be written, stored, and transmitted wirelessly. Tag data can then be forwarded by reader to enterprise software by way of RFID middleware layer. Study of how RFID is being utilized in manufacturing, with focus on automotive and aerospace. Letter grading. Mr. Gad (Sp)


C231G. Microscopic Energy Transport. (4) (Formerly numbered 231G) Lecture, four hours; outside study, eight hours. Requisite: course 105D. Exploration of basic principles of transportation of energy in nature and engineered systems. Analytical models of order reduction for single or multiple-dimensional systems. Application of models to energy transport, from micro- to macro-scales. Analytical or numerical methods to derive basic physical principles. Application to engineering systems. Letter grading. Mr. Fisher (F)

233. Nanoscience for Energy Technologies. (4) Lecture, four hours; laboratory, two hours; outside study, seven hours. Introduction to fundamental principles of energy transport, conversion, and storage at nanoscale, and recent developments for these technologies in various areas. Focus on nanotechnology. Topics include: transport science, solid state, quantum mechanics, electronics, magnetism, and statistical physics. Topic discussions are enhanced with examples that connect technological applications, fundamental fundamentals, and fundamental-solution-based nanotechnology to improve device performance and energy efficiency. Letter grading. Mr. Hu (Sp)

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 vehicle charging. May be repeated for credit with topic or instructor change. P/NP or letter grading. (Not offered 2020-21)

194. Research Group Seminars: Mechanical and Aerospace Engineering. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Designed for undergraduates who are part of research group. Discussion of research methods and current literature in field. Students present specific methods, results, or development at each meeting. May be repeated for credit with different topics. P/NP or letter grading. (Not offered 2020-21)

M236B. Introduction to Statistical Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Statistical mechanics: thermodynamic systems and associated distributions. Provides sound foundation for further studies in transport phenomena, plasma, chemical kinetics, micro/nanoscience and technology, and other related subjects. Concurrently scheduled with course C137. Letter grading. Mr. Abdou (Not offered 2020-21)

C238. Introduction to Statistical Thermodynamics. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 105A, 105D. Introduction to basic concepts and tools of statistical thermodynamics. Abstract concepts of entropy, temperature, and chemical potential are explained by developing these concepts from ground up using only mechanical and statistical principles. Discussion of equilibrium and nonequilibrium situations. Applications of statistical techniques to real-world problems. Letter grading. Mr. Abdou (Sp)

239B. Seminar: Recent Topics in Transport Phenomena. (4) Lecture, four hours; outside study, four to eight hours. Designed for graduate mechanical and aerospace engineering students. Lectures, discussions, student presentations, and projects in areas of current interest in transport phenomena. May be repeated for credit. S/U grading.
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, stability and turbulence, 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, course not to exceed eight hours. Designed for graduate mechanical and aerospace engineering students. Advanced study in areas of current interest in nuclear engineering, such as reactor safety, stability and turbulence, nuclear materials, and reactor design. May be repeated for credit with topic change. S/U grading.

239H. Special Topics in Fusion Physics, Engineering, and Technology. (2 to 4) Seminar, two to four hours; outside study, four to eight hours. Recommended requisite: courses 150A, 150B. 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. Recommended requisites: courses 101, 102, and 156A or 166A. Introduction to mechanical functions of human body; skeletal adaptations to optimize load transfer, mobility, and function. Dynamics and kinematics. Fluid mechanics applications. Heat and mass transfer. Power generation. Laboratory simulations and tests. Concurrently scheduled with course CM140. Letter grading.

Mr. Gupta (W)

242. Introduction to Multiferroic Materials. (4) Lecture, four hours; outside study, eight hours. Overview of different types of multiferroic materials, including strain mediated. Basic crystal structure of single-phase multiferroics, as well as fundamental physics underlying ferroelectricity and ferromagnetism. Material science description of these materials, with focus on linear and nonlinear behavior with associated mechanisms such as spin reorientation. Presentation of analytical tools necessary to predict material response to external stimuli, including hysteresis, fatigue, and magnetocrystalline anisotropy. Practical examples of large-scale chain mechanisms from combustion chemistry of several elements, etc. Letter grading.

Ms. Karagozian (Not offered 2020-21)

250A. Foundations of Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Corequisite: course 182B. Development and application of fundamental principles of fluid mechanics at graduate level, with emphasis on incompressible flow. Flow kinematics, basic equations, constitutive relations, exact solutions on the Navier/Stokes equations, vorticity dynamics, decomposition of flow fields, potential flow. Letter grading.

Mr. Eldredge, Mr. J. Kim (W)

250B. Viscous and Turbulent Flows. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Fundamental principles of fluid dynamics applied to study of fluid resistance. States of fluid motion discussed in order of advancing Reynolds number; wakes, boundary layers, instability, transition, and turbulent shear flows. Letter grading.

Ms. Karagözian (Sp)

250C. Compressible Flows. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 150A, 150B. Mechanisms for unsteady and steady inviscid and supersonic flows; method of characteristics; small disturbance theories (linearized and hyperbolic); shock dynamics. Letter grading.

Ms. Karagözian, Mr. Zhong (F)


Mr. J. Kim (Not offered 2020-21)

250E. Spectral Methods in Fluid Dynamics. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 82, 182B, 182C, 250A, 250B. Introduction to basic concepts and techniques of various Spectral methods applied to Partial differential equations. Particular emphasis on techniques of solving steady three-dimensional Navier- Stokes equations. Topics include spectral representation, pseudospectral, projection, boundary, etc. Letter grading.

Mr. G. Filbet (W)

250F. Hypersonic and High-Temperature Gas Dynamics. (4) Lecture, four hours; outside study, eight hours. Recommended requisite: course 250C. Molecular and chemical description of equilibrium and nonequilibrium hypersonic and high-temperature gas flows, chemical thermodynamics and statistical ther- modynamics for gas properties, equilibrium laws of real gases, vibrational and chemical rate processes, nonequilibrium flows of real gases, and computational fluid dynamics methods for nonequi- librium hypersonic flows. Letter grading.

Mr. J. Kim (Not offered 2020-21)

252A. Stability of Fluid Motion. (4) Lecture, four hours; outside study, eight hours. Requisite: course 150A. Mechanisms by which laminar flows can become unstable and lead to turbulence of secondary motions. Linear stability theory; thermal, centrifugal, and shear instabilities; boundary layer instability. Nonlinear aspects: sufficient criteria for stability, sub- critical instabilities, supercritical states, transition to turbulence. Letter grading.

Mr. Zhong (W)


(Not offered 2020-21)


Ms. Karagozian (F)

252D. Combustion Rate Processes. (4) Lecture, four hours; outside study, eight hours. Requisite: course 252C. Basic concepts in chemical kinetics: molecular collisions, distribution functions and aver- aging, semiempirical and ab initio potential surfaces, trajectory calculations, statistical reaction rate theo- ries. Practical examples of large-scale chain mecha- nisms from combustion chemistry of several elements, etc. Letter grading.

Ms. Karagozian (Not offered 2020-21)

252P. Plasma and Ionized Gases. (4) Lecture, four hours; outside study, eight hours. Enforced requisites: courses 82, 102, 150A, 182B, 182C. Special topics of current interest in advanced aerody- namic examples include transonic flow, hypersonic flow, sonic booms, and unstable aerodynamics. Let- ter grading.

Mr. Zhong (Not offered 2020-21)

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 aerody- namic examples include transonic flow, hypersonic flow, sonic booms, and unstable aerodynamics. Letter grading.

Mr. Zhong (Not offered 2020-21)


Mr. M. Otoke (Not offered 2020-21)

M256A. Linear Elasticity. (4) Same as Civil Engineering M230A.) Lecture, four hours; outside study, eight hours. Requisite: course 156A or 166A. Linear elastostatics. Cartesian tensors; infinitesimal strain theory; Cauchy stress tensor; equilibrium equations; linear constitutive relations; plane elastostatic problems, holes, corners, inclusions, cracks; three-dimensional problems of Kelvin, Bous- sinesq, and Cerruti. Introduction to boundary integral equation method. Letter grading.

Mr. W. Ju, Mr. Mal (F)

M256B. Nonlinear Elasticity. (4) Same as Civil Engi- neering M230B.) Lecture, four hours; outside study, eight hours. Requisite: course M256A. Kinematics of deformation, material and spatial coordinates, deforma- tion gradient tensor, nonlinear and linear strain tensors, strain displacement relations; balance laws, Cauchy and Piola 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. W. Ju, Mr. Mal (W)
261B. Finite Element Analysis for Solid and Structural Mechanics. (4) Lecture, four hours; outside study, eight hours. Requisite: course 156A or M256A, or consent of instructor. Strongly recommended requisites: courses M188, M256B, 261A. Application of finite elements to structural and solid-state-of-art modeling and design problems 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, static and dynamic 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 2020-21)

269D. Aeroelastic Effects in Structures. (4) Lecture, four hours; outside study, eight hours. Requisite: course M269A. Presentation of field of aeroelasticity from unified viewpoint of shell and plate theories, suspension bridges, buildings, and other structures. Derivation of aeroelastic operators and unsteady air loads from governing variational principles. Flow induced instability and receptivity of structural systems. Letter grading. Mr. Mal (Not offered 2020-21)

M270A. Linear Dynamic Systems. (4) (Same as Chemical Engineering M280A and Electrical and Computer Engineering M240A.) Lecture, four hours; outside study, eight hours. Requisite: course M270A or Electrical Engineering M240A. Existence and uniqueness of solutions to linear quadratic (LQ) optimal control problems for continuous-time and discrete-time linear systems. Hamiltonian systems and optimal control; algebraic and differential Riccati equations; implications of controllability, stabilizability, observability, and detectability. Solutions. Letter grading. Mr. Gibson (W)

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

C271A. Probability and Stochastic Processes in Dynamic Systems. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: courses 82, 107. Probability spaces, random variables, stochastic processes and sequences, applications, conditional expectation, Gaussian/Markov sequences, and minimum variance estimator (Kalman filter) with applications. Concurrently scheduled with course 272A. Letter grading. Mr. Speyer (F)

271B. Stochastic Estimation. (4) Lecture, four hours; outside study, eight hours. Enforced requisite: course C271A. Linear and nonlinear estimation theory, orthogonal projection lemma, Bayesian filtering theory, eraear algebra concepts and risk estimators. Letter grading. Mr. Speyer (W)

271C. Stochastic Optimal Control. (4) Lecture, four hours; outside study, eight hours. Requisite: course 271B. Stochastic dynamic programming, certainty equivalence principle, second-order information statistics; linear-quadratic-Gaussian problem, linear-exponential-Gaussian problem. Relationship between stochastic control and robust control. Letter grading. Mr. Parra-Vasquez (F)

271D. Seminar: Special Topics in Dynamic Systems Control. (4) Seminar, four hours; outside study, eight hours. Seminar on current research topics in dynamic systems modeling, control, and applications selected from different areas such as differential games, nonlinear estimation, adaptive filtering, industrial and aerospace applications, etc. Letter grading. Mr. Speyer (Not offered 2020-21)

Lecture, four hours; outside study, eight hours. Requisites: courses 171A, M270A. Graduate-level introduction to analysis and design of multivariable control systems. Emphasis on stability analysis and performance requirements, model uncertainty representations, and robustness considered in detail from frequency domain perspective. Structured singular value and its application to robust synthesis and design. Letter grading. Mr. M. Clooslay (Sp)

273A. Robust Control System Analysis and Design. (4) Lecture, four hours; outside study, eight hours. Focus on robust control of dynamical systems from input/output data, with emphasis on identification of discrete-time (digital) models of sampled-data systems. Coverage of conversion to continuous-time models. Models identified include transfer functions and state-space models. Discussion of applications in mechanical and aerospace engineering, including identification of flexible structures, microelectromechanical systems (MEMS) devices, and acoustic ducts. Letter grading.

Mr. C-J. Kim (F)

274. Microelectromechanical Systems (MEMS) Device Physics and Design. (4) Same as Bioengineering M252 and Electrical and Computer Engineering M252; lecture, one hour; outside study, seven hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Emphasis on recent developments. Simple structures designed with both foundry and nonfoundry processes. Letter grading. Mr. Chiou (Not offered 2020-21)


Letter grading. Mr. C-J. Kim (Not offered 2020-21)

285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 2, 102, 103, 105D. Introduction to fundamentals of physical phenomena occurring at interfaces and application of their knowledge to engineering problems. Fundamental concepts of interfacial phenomena, including wetting, interfacial surfaces, interfacial surface energies, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, microelectromechanical systems, and biological systems. Letter grading.

Mr. Pin (W)


287. Nanoscience and Technology. (4) Same as Electrical and Computer Engineering M257. Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanomechanics, top-down and bottom-up (self-assembled) nanofabrication; nanoelectronics; nanomaterials, nanoelectronics, and nanobiodetection technology. Introduction to new knowledge and techniques in nanoscale science and technology and inspire students to create new ideas in multidisciplinary nanoscale research. Letter grading. Mr. Y. Chen (W)

Letter grading. Mr. Li (Not offered 2020-21)

288. Microelectromechanical Systems (MEMS) Fabrication. (4) Same as Bioengineering M258 and Electrical and Computer Engineering M258B. Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: course M138B. 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)

289. Microsciences. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 102, 103, 105D. Fundamental issues of being in microscopic world of mechanical engineering of microscale devices. Topics include scale issues, surface tension, superhydrophobic surfaces and applications, and electrowetting and applications. Letter grading. Mr. C-J. Kim (F)

Mr. C-J. Kim (F)

C282. Microelectromechanical Systems (MEMS) Fabrication and Design. (4) Same as Bioengineering M252 and Electrical and Computer Engineering M252; lecture, one hour; outside study, seven hours. Introduction to MEMS design. Design methods, design rules, sensing and actuation mechanisms, microsensors, and microactuators. Emphasis on recent developments. Simple structures designed with both foundry and nonfoundry processes. Letter grading. Mr. Chiou (Not offered 2020-21)


Letter grading. Mr. C-J. Kim (Not offered 2020-21)

C285. Interfacial Phenomena. (4) Lecture, four hours; outside study, eight hours. Requisites: courses 2, 102, 103, 105D. Introduction to fundamentals of physical phenomena occurring at interfaces and application of their knowledge to engineering problems. Fundamental concepts of interfacial phenomena, including wetting, interfacial surfaces, interfacial surface energies, interfacial forces, interfacial hydrodynamics, and dynamics of triple line. Presentation of various applications, including wetting, change of phase (boiling and condensation), forms and emulsions, microelectromechanical systems, and biological systems. Letter grading.


C287. Nanoscience and Technology. (4) Same as Electrical and Computer Engineering M257. Lecture, four hours; outside study, eight hours. Introduction to fundamentals of nanoscale science and technology. Basic physical principles, quantum mechanics, chemical bonding and nanomechanics, top-down and bottom-up (self-assembled) nanofabrication; nanoelectronics; nanomaterials, nanoelectronics, and nanobiodetection technology. Introduction to new knowledge and techniques in nanoscale science and technology and inspire students to create new ideas in multidisciplinary nanoscale research. Letter grading. Mr. Y. Chen (W)

C288. Microelectromechanical Systems (MEMS) Fabrication. (4) Same as Bioengineering M258 and Electrical and Computer Engineering M258B. Lecture, three hours; discussion, one hour; outside study, eight hours. Enforced requisites: course M138B. 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)

C294A. Compliant Mechanism Design. (4) Mechanical and Aerospace Engineering / 125

Mechanical and Aerospace Engineering / 125
Master of Science in Engineering Online Programs

4732 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-6542

Jenn-Ming Yang, Ph.D., Associate Dean

Scope and Objectives

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.

Graduate Study

For information on graduate admission, see Graduate Programs on page 26.

The following introductory information is based on 2020-21 program requirements for UCLA graduate degrees. Complete program requirements are available at 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.

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

Vwani P. Roychowdhury, Ph.D. (Electrical and Computer Engineering), Area Director

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

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
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
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.

Reliability Engineering Program
Ali Mosleh, Ph.D., NAE (Civil and Environmental Engineering, Materials Science and Engineering, Mechanical and Aerospace Engineering), Area Director
The program is designed with a fresh perspective that addresses the current needs of the industry for ensuring reliability of engineered products and services, but also anticipates future needs and pushes frontiers into the realms of machine learning, advanced prognostics and health monitoring, and advanced methods to tackle reliability of complex cyber-physical-human (CPH) systems.

Systems Engineering Program
Jenn-Ming Yang, Ph.D. (Materials Science and Engineering), Interim Area Director
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 – Computer Networking
Mario Gerla, Ph.D. (Computer Science), Area Director
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 Engineering
Izhak Rubin, Ph.D. (Electrical and Computer Engineering), Area Director
The electrical engineering program covers a broad spectrum of specializations in communications and telecommunication, control systems, electromagnetics, embedded computing systems, engineering optimization, integrated circuits and systems, microelectromechanical systems (MEMS), nanotechnology, photonics and optoelectronics, plasma electronics, signal processing, and solid-state electronics.

M.S. in Engineering – Electronic Materials
Ya-Hong Xie, Ph.D. (Materials Science and Engineering), Area Director
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
The integrated circuits program includes analog integrated circuit (IC) design, design and modeling of VLSI circuits and systems, RF circuit and system design, signal 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
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 materials 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
Materials engineering is concerned with the design, fabrication, and testing of engineering materials that must simultaneously fulfill dimensional properties, quality con-
Schoolwide Programs and Courses

6426 Boelter Hall
Box 951601
Los Angeles, CA 90095-1601
310-825-9580
School website

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 26.

Lower-Division Courses
2. Technology and Society. (2) Lecture, two hours; discussion, one hour; outside study, three hours. Introduction to broader societal opportunities, impacts, and challenges arising from the application of and development of new technologies and digital media. Letter grading. (W)

10A. Introduction to Complex Systems Science. (5) Lecture, four hours; outside study, eight hours. How macroscopic patterns emerge dynamically from local interactions of large number of interdependent (often heterogeneous) entities, without global design or central control. Such emergent order, whose explanation cannot be reduced to explanations at level of individual entities, is ubiquitous in biology and human social systems, but also exists in certain physical processes such as earthquakes and some chemical reactions. Complexity also deals with how such systems undergo sudden changes, including catastrophic breakdowns, in absence of external force or central influence. Key aspect of biological and social collectives is their nature as complex adaptive systems, where individuals and groups adjust their behavior to external conditions. In biological and social systems, complexity science goes beyond traditional mathematics and statistics in its use of multigene computational models that better capture these complex, adaptive, and self-organizing phenomena. Letter grading.

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

20. First-Year Engineering Transition Bridge. (2) 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. Advanced preparation and early exposure to Fall Quarter mathematics, chemistry, and computer science curricula. Letter grading. (F, W, Sp)

21. Computing Immersion Summer Experience. (2) 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. Advanced preparation and early exposure to Fall Quarter mathematics, chemistry, and computer science curricula. Letter grading. (F, W, Sp)

M.S. in Engineering – Mechanical
Ajit K. Mal, Ph.D. (Mechanical and Aerospace Engineering), Area Director
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
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
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.

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 non-destructively.

22. Summer Bridge Program for Enhancing Engineering Students. (2) 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. Introductory course in advanced topics covered in upper-division engineering courses. Offered in summer only. P/NP grading.

23. Finding Industry Internship. (2) Seminar, two hours; outside study, four hours. Designed to engage engineering students in process of formal career development. Students learn about various components of internship/job application and practice preparing relevant materials. Prepares students for career-related social interactions. Development of skills and insights to successfully secure future opportunities, such as first industry internship. P/NP grading. (F, W)

24. Finding Undergraduate Research Opportunity. (2) Seminar, two hours; outside study, four hours. Designed to engage engineering students, primarily those without prior experience, in process of soliciting, securing, and beginning research. Students learn about various methods and resources used to obtain laboratory position. Exploration of opportunities and guidance on how to approach those openings. Offers students smooth transition into research laboratory. P/NP grading. (F, W, Sp)

25. Communicating Undergraduate Research Results. (2) Seminar, two hours; outside study, four hours. Designed to engage engineering students in process of communicating formal research. Students learn about various components required in publishing research. Offers templates and examples as guides for understanding technical presentations and writing. Development of skills and insights to successfully publish first research project. P/NP grading.

87. Introduction to Engineering Disciplines. (4) Lecture, four hours; discussion, four hours; outside study, four hours. Introduction to engineering as professional opportunity for freshman students by exploring difference between engineering disciplines and functions engineers perform. Development of skills and techniques for academic excellence through team process. Investigation of national need underlying current effort to increase participation of historically underrepresented groups in U.S. technological work force. Letter grading. Mr. Wesel (W)

95. Internship Studies in Engineering. (2 to 4) Seminar, two hours; outside study, four hours. Internship studies course supervised by associate dean or designated faculty members. Further supervision to be provided by organization for which student is 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. Wesel (F, W)

96A. Introduction to Engineering Design. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Introduction to engineering design while building teamwork and communication 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 vary.
96B. Introduction to Engineering Design: Digital Imaging. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for undergraduate Aerospace Engineering, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communication, and examining 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 manipulate telegraphic 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 narrative projects, and presentation of results. Letter grading. Mr. Stafsudd

96C. Introduction to Engineering Design: Internet of Things. (2) Lecture, one hour; laboratory, one hour; outside study, four hours. Recommended for undergraduate Aerospace Engineering, Bioengineering, Computer Science, Electrical Engineering, and Mechanical Engineering majors. Introduction to engineering design while building teamwork and communication, and examining 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 innovative and 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 advances in technology history with applications ranging from wearable devices for healthcare to residential monitoring systems, natural resource protection and management, intelligent vehicles and transportation systems, robotics systems, and energy conservation. Students will work on engineering design projects, preparation of short report describing projects, and presentation of results. Letter grading. Mr. Kaiser (ESP)

96D. Introduction to Engineering Design: Electrokardogram. (2) Lecture, 90 minutes; laboratory, 90 minutes; outside study, three hours. Students learn and use concepts and techniques in electrical circuit design and analysis, cardiac electrophysiology, bio-physics, and computer programming. Students work in teams to design, construct, and test circuit boards capable of measuring human electrocardiograms by capturing data with microcontroller, with computer analysis and display. Students present their designs orally and in writing. Letter grading. (W,SP)

96E. Introduction to Engineering Design: Go-Karts. (2) Lecture, 90 minutes; laboratory, 90 minutes; outside study, three hours. Students learn and use concepts and techniques in computer-aided design, finite element analysis, machining, electric motor performance, steering linkages, and general mechanical design and assembly to work in teams and construct and test go-karts. Students present their designs orally and in writing. Letter grading. (W,SP)

96F. Introduction to Engineering Design: Robot. (2) Lecture, 90 minutes; laboratory, 90 minutes; outside study, three hours. Introduction to basic concepts in aerospace engineering, computer-aided design, finite element analysis, 3D printing, carbon fiber layup, telemetry, general mechanical design and assembly, and machine shop fabrication. Concepts applied to team-based design, construction, and testing of small 3D-printed rockets and larger, high-power rockets. Students present their designs orally and in writing, and evaluate their performance against other student teams. Rockets fired from Mojave Desert launch site in class field trip. No prior experience necessary. Study led by experienced undergraduate members of Bruin Rocket Project. Meetings, and design and fabrication homework, make use of Makerspace facilities and tools. Letter grading. (W,SP)

99. Student Research Program. (1 to 2) Tutorial supervised research or other learning experience, 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 enroll in TENT 12 units (excluding this course). Individual contract required; consult Undergraduate Research Center. May be repeated. P/NP grading.

Upper-Division Courses

M101. Principles of Nanoscience and Nanotechnology. (4) Same as Materials Science M105. Lecture, four hours; discussion, one hour; outside study, seven hours. Enforced requisites: Chemistry 20A, 20B, Physics 1C. Introduction to understanding science encompassing structure, properties, and fabrication of technologically important nanoscale systems. New phenomena that emerge in very small systems (typically with feature sizes below few hundred nanome- ters) explained using basic concepts from physics and chemistry. Chemical, optical, and electronic properties, electron transport, structural stability, self-assembly, and templated assemblies of various nanostructures such as quantum dots, nanoparticles, quantum wires, quantum wells and multilayers, carbon nanotubes. Letter grading. Mr. Ozolins (F)

102. Synthetic Biosystems and Nanosystems Design. (4) Lecture, four hours; outside study, eight hours. Requisites: course M101, Life Sciences 3. Introduction to current progress in engineering to integrate biosciences and nanosciences into synthetic systems, where biological components are reengi- neered and rewired to perform desirable functions in both intracellular and cell-free environments. Discussion of basic technologies and systems 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. (W,SP) Mr. Liao

M103. Environmental Nanotechnology: Implications and Applications. (4) Same as Civil Engineering M165). Lecture, four hours; discussion, two hours; outside study, six hours. Recommended requisites: course M101, Introduction to potential implications of nanotechnology to environmental systems as well as potential application of nanotechnology to environmental protection. Technical contents include three main multidisciplinary physical, chemical, and biological properties of nanomaterials, (2) transport, reactivity, and toxicity of nanoscale materials in natural environmental systems, and (3) use of nanotechnology for energy and water production and environmental protection, monitoring, and remediation. Letter grading. Mr. Hoek (SP)

110. Introduction to Technology Management and Economics for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Fundamental principles of micro-level (individual, firm, and industry) and macro-level (government, in- ternational) economics as they relate to technology management. How individuals, firms, and govern- ments impact successful commercialization of high technology products and services. Letter grading. (W,SP) 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 technology commer- cialization. Introduction to the firm (and external in mar- ketplace) marketing and financing of high-technology innovation. Concepts include present value, future value, discounted cash flow, internal rate of return, return on asset, return on equity, return on investment, 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. (W,SP) Mr. Monbouquet (F,SP)

112. Laboratory to Market, Entrepreneurship for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Critical compo- nents of entrepreneurship, finance, marketing, human resources, and accounting disciplines as they impact management technology commercialization. Topics include intellectual property management, team building, market forecasting, and entrepre- neurial finance. Students work in small teams studying technology marketing plans bringing new technologies to market. Students select from set of available technology concepts, many generated at UCLA, that are in need of plans for movement to laboratory to market. Letter grading. Mr. Monbouquet (W,SP)

113. Product Strategy. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. De- signed for juniors/seniors. Introduction to current methods of specific analytical techniques needed in later courses in program. Development of basic understanding of statistical analysis. Letter grading. Mr. Pao

114. Statistics for Management Decisions. (4) Lecture, four hours; discussion, one hour; outside study, eight hours. Management as well as engineering decisions nearly always take place in environment characterized by un- certainty. Probability provides mathematical frame- work for understanding how to make rational decisions when outcomes of actions are certain. Application of probability to problem of reasoning from sample data, encompassing estimation, hypoth- esis testing, and regression analysis. Discussion of specific analytical techniques needed in later courses in program. Development of basic understanding of statistical analysis. Letter grading. Mr. Dolecek

163. Entrepreneurship and New Product Development for Engineers. (2) Seminar, two hours; outside study, four hours. Designed for seniors and graduate students. Identification of business opportunities and outline of basic requisites for viable business plans, followed by specific topics related to securing basic assets and resources needed to execute those plans. P/NP grading. Mr. Wesel

160. Entrepreneurship and Venture Initiation for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Not open to students with credit for Management 160. Focus on process and methodology for starting new venture. In- troduction to entrepreneurship from perspective of early-stage entrepreneur. Examines and frameworks on idea generation, market analysis, fundraising, corporate structures, and financial accounting for entrepreneurial endeavors. Focus on fundamentals of building a business, and also em- phasis on inherent experiential nature of entrepre- neurship and need for constant learning on this sub- ject. Letter grading. (F)

163. Entrepreneurship and New Product Development for Engineers. (4) Lecture, four hours; discussion, one hour; outside study, seven hours. Limited to juniors/seniors. Not open to students with credit for Management 163. Designed to deepen understand- ing of innovation and entrepreneurial processes re- lated to creating new products. Inquiry into why, what, and how of making new products. New prod- ucts are essential to any business (start-up or well- established) and thriving economies. Making suc- cessful new products requires various types of in- novation. Availability of digital technologies and global sources have accelerated pace of these innova- tions. (W)

180. Engineering of Complex Systems. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Designed for junior/senior engineering majors. Holistic view of engineering discipline, covering lifecycle of engineering and technologies used in industry today. Multidisciplinary systems engi- neering perspective in which aspects of electrical, mechanical, material, and software engineering are incorporated. Three specific case studies in commu-

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

188E. Experimental Courses in Engineering Writing. (4) Lecture, four hours; discussion, two hours; outside study, six hours. Enforced requisite: English Composition 3 or 3E. Not open for credit to students with credit for course 182EW, 183EW, 185EW, 182E5, 185E5, or 185EW. Limited to junior/senior engineering students. Professional and ethical considerations in practice of engineering and computer science. Emphasis on writing and writing within engineering and computer science. Writing and revision of about 20 pages total, including two individual technical essays. Readings address technical issues and writing form. Satisfies engineering writing requirement. 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 student or post-doctoral scholar. Designed to be accessible to undergraduate students in any science, technology, engineering, and mathematics (STEM) major. Offers undergraduate students opportunities to expand their understanding of graduate student research experience. Also offers opportunity for graduate students to learn about what their peers are doing. P/NP grading.


193. System Architecture. (4) Lecture, four hours; discussion, three hours; outside study, five hours. Enforced requisite: English Composition 3 or 3E. Not open for credit to students with credit for course 182EW, 183EW, or 185EW. Places engineering in broader societal context through examination of some of key ethical, legal, and regulatory issues and frameworks relevant to design and deployment of emerging technology products and services. Historical, legal, and technical frameworks work together and in relation to exploration of series of specific contemporary technology-related topics to examine their broader ramifications. Topics include driverless cars, algorithms and artificial intelligence, global supply chain for engineering products, cryptocurrencies and blockchain, net neutrality, and impact of technology on employment. Offers students tools enabling them to think more proactively and holistically about ethical and societal dimensions of their work as technology creators. Satisfies engineering writing requirement. Letter grading.

194. Directed Research in Engineering. (2 to 8) Projekt, four hours; outside study, eight hours. Enforced requisite: English Composition 3 or 3E. Not open for credit to students with credit for course 182EW, 183EW, or 185EW. Enforced requisite: junior/senior engineering students. Professional and ethical considerations in practice of engineering. Impact of technology on society and development of moral and ethical values. Contemporary environmental, biological, legal, and other issues created by new technologies. Emphasis on research and writing within engineering environments. Writing and revision of about 20 pages total, including two individual technical essays and one team-written research report. Readings address technical issues and writing form. Satisfies engineering writing requirement. Letter grading.

200. Program Management Principles for Engineers and Professionals. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of necessary processes and procedures to successfully manage technology programs. Review of fundamentals of project planning, organization, scheduling, and performance tracking methods to provide program manager with necessary information to support decision-making process that provides high-quality products on time and within budget. Letter grading.

201. Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Designed for graduate students. Practical review of major elements of system engineering process. Coverage of key elements of systems requirement definition, product development cycle, functional analysis, system synthesis and trade studies, budget allocations, risk management metrics, review and audit activities and the management of schedule. Letter grading.

202. Reliability, Maintainability, and Supportability. (4) Lecture, four hours; outside study, eight hours. 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 interplay using probability theory. Topics also include fault detections and isolation and parts obsolescence. Discussion of 6-sigma process, one effective design and manufacturing methodology, to address availability, maintainability, and supportability. Letter grading.

203. System Architecture. (4) Lecture, four hours; outside study, eight hours. 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 architecting. Introduction to architecting methodology—paradigm and tool support for architecting through analysis of architecture designs of major existing systems. Discussion of selected elements of architectural practices, such as representation models, design progression, and architecture frameworks. Examination of professionalization of system architecting. Letter grading.

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 successfully handle and protect important systems involves more than composing systems from network security, computer security, data security, cryptography, etc. One can use most secure components, and resulting system could still be vulnerable. Skills learned ensure that systems are architected, designed, implemented, tested, and operated for specific levels of trust. Aspects include assessing vulnerability and risk for systems, establishing protection concepts, and using threat models to evaluate system architectures; translating architecture into system design and verifying correctness of design; and constructing and following trusted development implementation procedures. Letter grading.

205. Model-Based Systems Engineering. (4) Lecture, four hours; outside study, eight hours. Model-based systems engineering (MBSE) and systems modeling language (SysML) taught through lectures and readings, individual projects, and one group project. Lectures and readings to provide students with conceptual framework and vocabulary. Individual projects enable students to develop basic skills for creating SysML requirements and structural and behavioral diagrams. In group project students learn to packagage, compartmentalize, and integrate smaller efforts while being constrained to meet stakeholder requirements. Industry-recognized credentials may be obtained, as course covers Object Management Group (OMG) Certified Systems Modeling Professional (OCSMP) tests, such as Model User and Model Builder Fundamentals and Model Builder Intermediate. Letter grading.

206. Engineering for Systems Assurance. (4) Lecture, four hours; outside study, eight hours. Recommended requisites: course 204, Computer Science 20, and Engineering 100. Systems are complex systems of functions and services. How to understand needs of users, analysis of requirements and derived requirements, creation of various system architecture products, and design and integration of various system components into systems that perform these functions and services. System assurance addresses confidence that systems meet specified operational requirements based on evidence provided by applying as
210. Operations and Supply Chain Management. (4) Lecture, four hours; outside study, eight hours. Introduction to strategic and operating issues and decisions involved in managing enterprises. Operational processes use organization’s resources to transform inputs into goods and utilize them to provide service, or do both. Conceptual framework and set of analytical tools provided to enable students to better understand why processes behave as they do. Given this understanding, students are able to involve themselves in organization’s defining strategic decisions, those related to key processes affecting organizational unit’s performance. Letter grading.

Mr. Vandenberghe (Sp)

211. Financial Management. (4) Lecture, four hours; outside study, eight hours. Introduction to concepts reflecting material generally covered in certain MBA core and elective courses. Integration of both theory and practice to introduce essential conceptual building blocks in accounting and finance—and empirical practice—to emphasize how these theories are actually implemented in real world. Cases, comprehensive problems, and recent events presented to provide students with much hands-on experience in applying material presented as possible. Letter grading.

Mr. J-M. Yang

212. Intellectual Property Law and Strategy. (4) Lecture, four hours; outside study, eight hours. Prior knowledge of legal doctrines or materials not required. Intellectual property law is not just topic for lawyers. Engineers who have design responsibilities must understand how legal system in some instances protects their designs and in other instances stands as obstacle to what would otherwise be most efficient design choice. Engineers with management responsibilities must understand intellectual property law implications for everything from pricing to strategic partnerships. Examination of intellectual property law, not only by learning fundamental rules associated with patent, copyright, trademark, and trade secret protection, but by studying business strategies that these rules support. Examples and case studies to be taken from across content, technology, and pharmaceutical industries. Letter grading.

Mr. Lichtman, Mr. J-M. Yang (F)

213. Data and Business Analytics. (4) Lecture, four hours; outside study, eight hours. Coverage of wide variety of spreadsheet models that can be used to solve business and engineering problems, with emphasis on mastery of Excel spreadsheet modeling as integral part of analytic decision making. Managerial models include data modeling, regression and forecasting, linear programming, network and distribution models, integer programming, nonlinear programming, and Monte Carlo simulation. Problems from operations, finance, and marketing taught by spreadsheet examples and describe general management situation from various industries and disciplines. Development of spreadsheet models to facilitate decision making. Letter grading.

Mr. Mosleh (W)

214. Management Communication. (4) Lecture, four hours. Exploration of knowledge, attributes, skills, and strategies necessary to succeed communicatively in workplace, with focus on business presentation skills, visual and verbal persuasion skills, and interpersonal communication skills. Letter grading.

Mr. J-M. Yang

215. Entrepreneurship for Engineers. (4) Lecture, four hours; outside study, eight hours. Limited to graduate engineering students. Topics in starting and developing high-tech enterprises and intended for students who wish to complement their technical education with introduction to entrepreneurship. Letter grading.

Mr. Abe, Mr. Cong, Mr. Wesel (W)

299. Capstone Project. (4) Activity, 10 hours. Preparation for final course in MS program. Project course that satisfies UCLA final comprehensive examination requirement of MS online degree in Engineering. Projects are undertaken by teams from across content, technology, and pharmaceutical industries. Letter grading.

Mr. Lynch (F,W,Sp)

375. Teaching Apprentice Practicum. (1 to 4) Seminar, four hours; outside study, eight hours. Opportunity for engineering writing contexts. Practical concerns of preparing students to write course assignments, marking and grading essays, and conducting peer reviews and conferences. S/U grading. (F,W,Sp)

501. Cooperative Program. (2 to 8) Tutorial, to be arranged. Preparation: consent of graduate adviser and graduate dean, and host campus instructor, department chair, and graduate dean. Used to record enrollment of UCLA students in courses taken under cooperative arrangements with USC, S/U grading.
Center for Domain-Specific Computing (CDSC)

National Science Foundation (NSF) Expeditions in Computing Program and InTrans Program

Jason (Jingsheng) Cong, Ph.D. (Computer Science), Director

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. 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. Its 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 multicore 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 -in-a-cluster, customized to an application domain, to enable disruptive innovations in that domain. CDSC has successfully demonstrated this approach in the domains of machine learning, medical image processing, and precision medicine.

The current team consists of highly accomplished researchers with diversified backgrounds, including computer science and engineering, electrical engineering, medicine, and applied mathematics from UCLA, Cornell University, and Georgia Institute of Technology. CDSC offers many research opportunities for graduate students, and summer research opportunities for undergraduate students.

CDSC was originally funded by the National Science Foundation (NSF) 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 research programs are supported by NSF, Semiconductor Research Corporation (SRC) Joint University Microelectronics Program (JUMP), and a number of industrial partners worldwide.

Center for Encrypted Functionalities

National Science Foundation (NSF) Secure and Trustworthy Cyberspace FRONTIER Award

Amit Sahai, Ph.D. (Computer Science), Director

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 (TANMS)

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

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 (California State University, Northridge; Cornell University; Northeastern University; UC Berkeley; UCLA; and University of Texas at Dallas) to understand and develop new nanoscale multiferroic devices. The fundamental research activities work synergistically with the center’s 10 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 helps educate the next generation of engineering leaders. TANMS promotes an inclusive atmosphere, producing a more innovative and diverse research environment compared to conventional engineering center cultures.

Center of Excellence for Green Nanotechnologies (CEGN)

Kang L. Wang, Ph.D. (Electrical and Computer Engineering), Director

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 Samueli collaborate in CEGN under
KACST’s established Joint Center of Excellence Program (JCEP) to promote educational technology transfer and research exchanges. KACST has an agreement with UCLA for research in nanoelectronics and clean energy for the next three years. KACST is both Saudi Arabia’s national science agency and its premier national laboratory. CEGN was awarded an additional $11 million through 2021 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

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.

The **Named Data Networking Project** investigates a new Internet architecture, called named data networking (NDN), that 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 (SMERC)**
Rajit Gadh, Ph.D. (Mechanical and Aerospace Engineering), Director

**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 furnishes thought leadership through partnership between utilities, renewable energy companies, technology providers, electric vehicle and electric appliance manufacturers, Department of Energy (DOE) research laboratories, and universities, so as to collectively work on envisioning, planning, and executing the smart grid of the future. The partnership recently launched the Energy for a Smart Grid (ESmart) Industry Consortium. It is expected that this smart grid will 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 was a participant in the Los Angeles Department of Water and Power (LADWP) Regional Smart Grid Demonstration Project, which was funded by DOE at an estimated $120 million for LADWP and its partners combined. Also, a SMERC electric vehicle microgrid demonstration project was funded by the California Energy Commission.

**Center for Synthetic Control Across Lengthscales for Advancing Rechargeables (SCALAR)**

**Department of Energy (DOE) Energy Frontier Research Center**
Sarah Tolbert, Ph.D. (Chemistry and Biochemistry, Materials Science and Engineering), Director

**SCALAR** aims to use the power of synthetic materials chemistry to design materials, interfaces, and architectures that address long-standing problems in electrochemical energy storage systems. A vital aspect of the SCALAR program is the simultaneous design of new functional materials at the atomic, nanoscale, and electrode levels in an effort to bring about meaningful advances in battery performance. The electrochemical energy storage problems that SCALAR addresses fall into three areas: increasing the fundamental charge storage properties of electrode materials, reducing resistive losses in materials and electrodes, and improving the reversibility and cycling stability of electrode materials.

SCALAR further takes advantage of the dynamic Southern California region, which houses a large number of world-class research universities. Four of them—Caltech, UC Santa Barbara, UC San Diego, and University of Southern California—and the Stanford Linear Accelerator Center national laboratory, join lead institution UCLA to make a regional hub for battery research that leverages all partners’ proximity and complementary facilities.

**WIN Institute of Neurotronics (WINs)**

**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, WINs focuses on cutting-edge research including nanostructures for high-efficiency solar cells, patterned electrode materials, reducing resistive losses in materials and electrodes, and improving the reversibility and cycling stability of electrode materials.

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.
# B.S. in Aerospace Engineering

## Aeronautics Track Curriculum

### FRESHMAN YEAR

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<tr>
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### SOPHOMORE YEAR

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### JUNIOR 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.
² Counts as Engineering Concepts for ABET, total units Engineering Concepts = 85.
³ Students should consult the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see pages 22 and 23 for details).
⁴ See page 111 for list of electives.
# B.S. in Aerospace Engineering

## Space Track Curriculum

### FRESHMAN YEAR

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### SOPHOMORE YEAR

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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 pages 22 and 23 for details).
4. See page 111 for list of electives.
# B.S. in Bioengineering Curriculum

## FRESHMAN YEAR

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## SOPHOMORE YEAR

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<td>Mathematics 32B — Calculus of Several Variables&lt;sup&gt;1&lt;/sup&gt;</td>
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## JUNIOR YEAR

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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 = 74.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see pages 22 and 23 for details).
## B.S. in Chemical Engineering

### Chemical Engineering Core Option Curriculum

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<td>Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity</td>
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### SOPHOMORE YEAR

| 1st Quarter |       |
| Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering | 4 |
| Chemistry and Biochemistry 20AL — General Chemistry Laboratory I | 4 |
| Mathematics 32B — Calculus of Several Variables | 4 |
| Physics 1C — Electrodynamics, Optics, and Special Relativity | 5 |
| **2nd Quarter** |       |
| Chemical Engineering 45 — Biomolecular Engineering Fundamentals | 4 |
| Chemical Engineering 102A — Thermodynamics I | 4 |
| Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy | 4 |
| Mathematics 33A — Linear Algebra and Applications | 4 |
| **3rd Quarter** |       |
| Chemical Engineering 102B — Thermodynamics II | 4 |
| Civil and Environmental Engineering M20 — Introduction to Computer Programming with MATLAB | 4 |
| Mathematics 33B — Differential Equations | 4 |
| UCLA Samueli GE Elective | 4 |

### JUNIOR YEAR

| 1st Quarter |       |
| Chemical Engineering 101A — Transport Phenomena | 4 |
| Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering | 4 |
| UCLAL Samueli GE Elective | 5 |
| **2nd Quarter** |       |
| Chemical Engineering 101B — Transport Phenomena II: Heat Transfer | 4 |
| Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I | 4 |
| UCLAL Samueli GE Elective | 5 |
| **3rd Quarter** |       |
| Chemical Engineering 101C — Mass Transfer | 4 |
| Chemical Engineering 103 — Separation Processes | 4 |
| UCLAL Samueli GE Elective | 5 |

### SENIOR YEAR

| 1st Quarter |       |
| Chemical Engineering 104B — Chemical and Biomolecular Engineering Laboratory II | 6 |
| Chemical Engineering 106 — Chemical Reaction Engineering | 4 |
| Chemical Engineering Elective | 4 |
| Technical Breadth Course | 4 |
| **2nd Quarter** |       |
| Chemical Engineering 107 — Process Dynamics and Control | 4 |
| Chemical Engineering 108A — Process Economics and Analysis | 4 |
| Technical Breadth Course | 4 |
| UCLAL Samueli GE Elective | 5 |
| **3rd Quarter** |       |
| Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis | 4 |
| Chemical Engineering Elective | 4 |
| Technical Breadth Course | 4 |

### TOTAL

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 pages 22 and 23 for details).
## FRESHMAN YEAR

### 2nd Quarter
- **Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity**
- **Mathematics 32A—Calculus of Several Variables**
- **Physics 18/4A—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory**

### 3rd Quarter
- **Chemical Engineering 103—Separation Processes**
- **Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory I**
- **UCLA Samueli GE Elective**

### JUNIOR YEAR

### 1st Quarter
- **Chemical Engineering 101A—Transport Phenomena II**
- **Chemical Engineering 109—Numerical and Mathematical Methods in Chemical and Biological Engineering**
- **UCLA Samueli GE Elective**

### 2nd Quarter
- **Chemical Engineering 101B—Transport Phenomena II: Heat Transfer**
- **Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory I**
- **UCLA Samueli GE Elective**

### SENIOR YEAR

### 1st Quarter
- **Chemical Engineering 104B—Chemical and Biomolecular Engineering Laboratory II**
- **Chemical Engineering 106—Chemical Reaction Engineering**
- **Chemical Engineering CM145—Molecular Biotechnology for Engineers**
- **Chemical Engineering 102A—Thermodynamics I**

### 2nd Quarter
- **Chemical Engineering 107—Process Dynamics and Control**
- **Chemical Engineering 106A—Process Economics and Analysis**
- **Technical Breadth Course**
- **UCLA Samueli GE Elective**

### 3rd Quarter
- **Chemical Engineering 108A—Chemical Process Computer-Aided Design and Analysis**
- **Technical Breadth Course**
- **UCLA Samueli GE Elective**

### TOTAL

### Notes

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 pages 22 and 23 for details).
## B.S. in Chemical Engineering
### Biomolecular Engineering Option Curriculum

### FRESHMAN YEAR

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<td>Mathematics 31B—Integration and Infinite Series</td>
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<td>Physics 1A—Mechanics</td>
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<td>Chemistry and Biochemistry 30A—Organic Chemistry I: Structure and Reactivity</td>
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### SOPHOMORE YEAR

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<td>Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory I</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 = 64.
3. Students should contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see pages 22 and 23 for details).
# B.S. in Chemical Engineering
## Environmental Engineering Option Curriculum

### FRESHMAN YEAR

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<td>Chemical Engineering 109—Numerical and Mathematical Methods in Chemical and Biological Engineering</td>
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<td>Chemical Engineering 101B—Transport Phenomena II: Heat Transfer</td>
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<td>Chemical Engineering 104A—Chemical and Biomolecular Engineering Laboratory II</td>
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<td>Chemical Engineering 104B—Chemical and Biomolecular Engineering Laboratory II</td>
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<td>Chemical Engineering 106—Chemical Reaction Engineering</td>
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<td>Chemical Engineering 107—Process Dynamics and Control</td>
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<td>Chemical Engineering 108A—Process Economics and Analysis</td>
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<td>Chemical Engineering 108B—Chemical Process Computer-Aided Design and Analysis</td>
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<td>TOTAL</td>
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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 pages 22 and 23 for details).
B.S. in Chemical Engineering

Semiconductor Manufacturing Engineering Option Curriculum

FRESHMAN YEAR

1st Quarter
- Chemical Engineering 10 — Introduction to Chemical and Biomolecular Engineering 2
- Chemistry and Biochemistry 20A — Chemical Structure 1
- English Composition 3 — English Composition, Rhetoric, and Language
- Mathematics 31A — Differential and Integral Calculus 1

2nd Quarter
- Chemistry and Biochemistry 20B/20L — Chemical Energetics and Change/General Chemistry Laboratory 1
- Mathematics 31B — Integration and Infinite Series 1
- Physics 1A — Mechanics 1

3rd Quarter
- Chemistry and Biochemistry 30A — Organic Chemistry I: Structure and Reactivity 1
- Mathematics 32A — Calculus of Several Variables 1
- Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory 1

SOPHOMORE YEAR

1st Quarter
- Chemical Engineering 100 — Fundamentals of Chemical and Biomolecular Engineering 2
- Chemistry and Biochemistry 30AL — General Chemistry Laboratory II 1
- Mathematics 32B — Calculus of Several Variables 1
- Physics 1C — Electrodynamics, Optics, and Special Relativity 1

2nd Quarter
- Chemical Engineering 45 — Biomolecular Engineering Fundamentals 2
- Chemical Engineering 102A — Thermodynamics IP 2
- Chemistry and Biochemistry 30B — Organic Chemistry II: Reactivity, Synthesis, and Spectroscopy 1
- Mathematics 33A — Linear Algebra and Applications 1

3rd Quarter
- Chemical Engineering 102B — Thermodynamics II 2
- Civil and Environmental Engineering M20 — Introduction to Computer Programming with MATLAB 2
- Mathematics 33B — Differential Equations 1
- UCLA Samueli GE Elective 3

JUNIOR YEAR

1st Quarter
- Chemical Engineering 101A — Transport Phenomena I 2
- Chemical Engineering 109 — Numerical and Mathematical Methods in Chemical and Biological Engineering 2
- UCLA Samueli GE Elective 3

2nd Quarter
- Chemical Engineering 101B — Transport Phenomena II: Heat Transfer 2
- Chemical Engineering 104A — Chemical and Biomolecular Engineering Laboratory I 2
- UCLA Samueli GE Elective 3

3rd Quarter
- Chemical Engineering 101C — Mass Transfer 2
- Chemical Engineering 103 — Separation Processes 2
- UCLA Samueli GE Elective 3

SENIOR YEAR

1st Quarter
- Chemical Engineering 106 — Chemical Reaction Engineering 2
- Chemical Engineering or Materials Science and Engineering Elective 2
- Technical Breadth Course 1

2nd Quarter
- Chemical Engineering 104C/104CL — Semiconductor Processing/Laboratory 2
- Chemical Engineering 107 — Process Dynamics and Control 2
- Chemical Engineering 108A — Process Economics and Analysis 2
- Technical Breadth Course 1

3rd Quarter
- Chemical Engineering 108B — Chemical Process Computer-Aided Design and Analysis 2
- Chemical Engineering C116 — Surface and Interface Engineering 2
- Technical Breadth Course 1
- UCLA Samueli GE Elective 3

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 pages 22 and 23 for details).
# B.S. in Civil Engineering Curriculum

## FRESHMAN YEAR

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<td>Mathematics 31A — Differential and Integral Calculus(^3)</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 32A — Calculus of Several Variables(^1)</td>
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<td>Physics 1B/4AL — Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory(^2)</td>
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## SOPHOMORE YEAR

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<td>Civil and Environmental Engineering 91 (Statics) or Mechanical and Aerospace Engineering 101 (Statics and Strength of Materials)(^2)</td>
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<td>Civil and Environmental Engineering 102 — Dynamics of Particles and Bodies(^2)</td>
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<td>Civil and Environmental Engineering 108 — Introduction to Mechanics of Deformable Solids(^3)</td>
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<td>Mathematics 31B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)(^3)</td>
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<td>Mechanical and Aerospace Engineering 103 — Elementary Fluid Mechanics(^2)</td>
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## JUNIOR YEAR

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<td>Civil and Environmental Engineering 135A — Elementary Structural Analysis(^2)</td>
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<td>Civil and Environmental Engineering 150 — Introduction to Hydrology(^2)</td>
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<td>Civil and Environmental Engineering 153 — Introduction to Environmental Engineering Science(^2)</td>
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<tr>
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<td>Chemical Engineering 102A (Thermodynamics I) or Mechanical and Aerospace Engineering 105A (Introduction to Engineering Thermodynamics)(^2)</td>
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<td>Civil and Environmental Engineering 103 — Applied Numerical Computing and Modeling in Civil and Environmental Engineering(^2)</td>
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## SENIOR YEAR

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<td>UCLA Samuels GE Elective(^1)</td>
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<td>Major Field Electives (2)(^2,4)</td>
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<tr>
<td>3rd</td>
<td>Major Field Elective(^2,4)</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 pages 22 and 23 for details).
4. Must include required courses for two of the major field areas listed on page 51.
# B.S. in Computer Engineering Curriculum

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<td>Computer Science 32—Introduction to Computer Science II</td>
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<td>Physics 1A—Mechanics I</td>
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<td><strong>3rd Quarter</strong></td>
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<td>Computer Science 33—Introduction to Computer Organization</td>
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<tr>
<td>Engineering 96C—Introduction to Engineering Design: Internet of Things</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables I</td>
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<td>Electrical and Computer Engineering 3—Introduction to Electrical Engineering</td>
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<td>Physics 4AL (Mechanics Laboratory) or 4BL (Electricity and Magnetism Laboratory)</td>
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<td>Computer Science 35L—Software Construction Laboratory I</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 102—Systems and Signals</td>
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<td>Computer Science 11I—Operating Systems Principles I</td>
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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 180—I Introduction to Algorithms and Complexity</td>
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<td>Computer Science M151B or Electrical and Computer Engineering M116C—Computer Systems Architecture</td>
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<td>Computer Science Elective I</td>
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<td><strong>TOTAL</strong></td>
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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 pages 22 and 23 for details).
4. See page 65 or 86 for list of electives.
### B.S. in Computer Science Curriculum

#### FRESHMAN YEAR

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<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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#### JUNIOR YEAR

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<td>Computer Science 131—Programming Languages</td>
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<tr>
<td></td>
<td>Additional coursework to meet 180 unit requirement</td>
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<tr>
<td>TOTAL</td>
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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 pages 22 and 23 for details).
4. See page 64 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

<table>
<thead>
<tr>
<th>1st Quarter</th>
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<tbody>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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</tr>
<tr>
<td>Mathematics 31A—Differential and Integral Calculus</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Computer Science 32—Introduction to Computer Science II</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series</td>
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<tr>
<td>Physics 1A—Mechanics</td>
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<table>
<thead>
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<th>3rd Quarter</th>
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<tbody>
<tr>
<td>Computer Science 33—Introduction to Computer Organization</td>
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<tr>
<td>Mathematics 32A—Calculus of Several Variables</td>
<td>4</td>
</tr>
<tr>
<td>Physics 1B—Oscillations, Waves, Electric and Magnetic Fields</td>
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## SOPHOMORE YEAR

<table>
<thead>
<tr>
<th>1st Quarter</th>
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<tbody>
<tr>
<td>Computer Science 35L—Software Construction Laboratory</td>
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<tr>
<td>Computer Science M51A or Electrical and Computer Engineering M16—Logic Design of Digital Systems</td>
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<td>Mathematics 32B—Calculus of Several Variables</td>
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<td>Physics 1C—Electrodymanics, Optics, and Special Relativity</td>
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<thead>
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<tbody>
<tr>
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<tr>
<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>UCLA Samueli Ethics Course</td>
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<tbody>
<tr>
<td>Computer Science 180—I Introduction to Algorithms and Complexity</td>
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<tr>
<td>Electrical and Computer Engineering 3—Introduction to Electrical Engineering</td>
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<tr>
<td>Mathematics 33B—Differential Equations</td>
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## JUNIOR YEAR

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<tbody>
<tr>
<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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<tbody>
<tr>
<td>Computer Science 131—Programming Languages</td>
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<tr>
<td>Computer Science M102A or Electrical and Computer Engineering M116C—Introductory Digital Design Laboratory</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals</td>
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<tbody>
<tr>
<td>Computer Science 118—Computer Network Fundamentals</td>
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<tr>
<td>Computer Science M151B or Electrical and Computer Engineering M116C—Computer Systems Architecture</td>
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<tr>
<td>Electrical and Computer Engineering 115C—Digital Electronic Circuits</td>
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## SENIOR YEAR

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<tbody>
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<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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<tr>
<td>Computer Science Elective</td>
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<td>UCLA Samueli GE Elective</td>
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<tbody>
<tr>
<td>Computer Science Elective</td>
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<tr>
<td>Electrical and Computer Engineering Elective</td>
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<tr>
<td>Technical Breadth Course</td>
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<td>UCLA Samueli GE Elective</td>
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<table>
<thead>
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<tbody>
<tr>
<td>Computer Science Elective</td>
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<tr>
<td>UCLA Samueli GE Elective</td>
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<td>Technical Breadth Course</td>
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<td>Additional coursework to meet 180 unit requirement</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 contact the Office of Academic and Student Affairs for approved lists in the categories of technical breadth and GE (see pages 22 and 23 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 this unit.
B.S. in Electrical Engineering Curriculum

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<thead>
<tr>
<th>FRESHMAN YEAR</th>
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<tbody>
<tr>
<td>1st Quarter</td>
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<tr>
<td>Computer Science 31—Introduction to Computer Science</td>
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<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>
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<tr>
<td>2nd Quarter</td>
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</tr>
<tr>
<td>Chemistry and Biochemistry 20A—Chemical Structure</td>
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<tr>
<td>Computer Science 32—Introduction to Computer Science II</td>
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<tr>
<td>Mathematics 31B—Integration and Infinite Series</td>
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</tr>
<tr>
<td>Physics 1A—Mechanics</td>
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<tr>
<td>3rd Quarter</td>
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<tr>
<td>Electrical and Computer Engineering M6 (or Computer Science M51A)—Logic Design of Digital Systems</td>
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<td>Mathematics 32A—Calculus of Several Variables</td>
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<tr>
<td>Physics 1B/4AL—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory</td>
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<table>
<thead>
<tr>
<th>SOPHOMORE YEAR</th>
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<tbody>
<tr>
<td>1st Quarter</td>
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<tr>
<td>Electrical and Computer Engineering 3—Introduction to Electrical Engineering</td>
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<tr>
<td>Mathematics 32B—Calculus of Several Variables</td>
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<tr>
<td>Mathematics 33A—Linear Algebra and Applications</td>
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<tr>
<td>Physics 1C—Electrodynamics, Optics, and Special Relativity</td>
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<tr>
<td>Electrical and Computer Engineering 10 (Circuit Theory I) and 11L (Circuits Laboratory I)</td>
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<td>Electrical and Computer Engineering 102—Systems and Signals</td>
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<tr>
<td>Mathematics 33B—Differential Equations</td>
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<td>Physics 4BL—Electricity and Magnetism Laboratory</td>
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<td>Electrical and Computer Engineering 2—Physics for Electrical Engineers</td>
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<tbody>
<tr>
<td>1st Quarter</td>
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<tr>
<td>Electrical and Computer Engineering 113—Digital Signal Processing</td>
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<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics</td>
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<td>Electrical and Computer Engineering Core Course</td>
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<td>Electrical and Computer Engineering Core Course</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>Electrical and Computer Engineering Design Course</td>
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<td>Electrical and Computer Engineering Elective</td>
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<td>Technical Breadth Course</td>
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<tr>
<td>UCLA Samueli GE Elective</td>
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<td>3rd Quarter</td>
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<td>Electrical and Computer Engineering or UCLA Samueli Elective</td>
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</table>

TOTAL: 182

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 pages 22 and 23 for details).
4. See page 85 for list of core courses.
## B.S. in Materials Engineering Curriculum

### Materials Engineering Option Curriculum

### Freshman Year

**1st Quarter**
- Chemistry and Biochemistry 20A—Chemical Structure
- English Composition 3—English Composition, Rhetoric, and Language
- Materials Science and Engineering 10—Freshman Seminar: New Materials
- Mathematics 31A—Differential and Integral Calculus

**2nd Quarter**
- Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory
- Mathematics 31B—Integration and Infinite Series
- Physics 1A—Mechanics

**3rd Quarter**
- Mathematics 32A—Calculus of Several Variables
- Physics 1B—Oscillations, Waves, Electric and Magnetic Fields

### Sophomore Year

**1st Quarter**
- Mathematics Science and Engineering 110/110L—Introduction to Materials Characterization A/Laboratory
- Mathematics 32B—Calculus of Several Variables
- Physics 1C—Electrodynamics, Optics, and Special Relativity

**2nd Quarter**
- Mathematics Science and Engineering 150—Introduction to Polymers
- Mathematics 33A—Linear Algebra and Applications
- UCLA Samuei GE Elective

**3rd Quarter**
- Civil and Environmental Engineering 20 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)
- Electrical and Computer Engineering 100—Electrical and Electronic Circuits
- Mathematics 33B (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)
- Technical Breadth Course

### Junior Year

**1st Quarter**
- Materials Science and Engineering Laboratory Course
- Materials Science and Engineering 130—Phase Relations in Solids
- Mechanical and Aerospace Engineering 101—Statics and Strength of Materials
- Technical Breadth Course

**2nd Quarter**
- Materials Science and Engineering 131/131L—Diffusion and Diffusion-Controlled Reactions/Laboratory
- Mathematics Science and Engineering 143A—Mechanical Behavior of Materials
- UCLA Samuei GE Elective

**3rd Quarter**
- Civil and Environmental Engineering 108—Introduction to Mechanics of Deformable Solids
- Materials Science and Engineering 132—Structures and Properties of Metallic Alloys
- Materials Science and Engineering Laboratory Course
- UCLA Samuei GE Elective

### Senior Year

**1st Quarter**
- Materials Science and Engineering Elective
- Materials Science and Engineering 160—Introduction to Ceramics and Glasses
- UCLA Samuei Ethics Course
- Upper-Division Mathematics Course

**2nd Quarter**
- Materials Science and Engineering Elective
- Materials Science and Engineering 120—Physics of Materials
- Materials Science and Engineering 140A—Materials Selection and Engineering Design A
- UCLA Samuei GE Elective

**3rd Quarter**
- Materials Science and Engineering 140B—Materials Selection and Engineering Design B
- Materials Science and Engineering Elective
- Technical Breadth Course
- UCLA Samuei GE Elective

### Total

**180**

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 pages 22 and 23 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 103 for list of approved mathematics courses.
# B.S. in Materials Engineering Curriculum

## Electronic Materials Option Curriculum

### Freshman Year

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<th>Course Title</th>
<th>Units</th>
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<tr>
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<td>English Composition 3—English Composition, Rhetoric, and Language</td>
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<tr>
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<td>Materials Science and Engineering 10—Freshman Seminar: New Materials</td>
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<td>Mathematics 31A—Differential and Integral Calculus</td>
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<td>Chemistry and Biochemistry 208/20L—Chemical Energetics and Change/General Chemistry Laboratory</td>
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<td>Physics IA—Mechanics</td>
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### Sophomore Year

<table>
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<th>Course Title</th>
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<tbody>
<tr>
<td>1st</td>
<td>Mathematics 32B—Calculus of Several Variables</td>
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<td></td>
<td>Physics IC—Electrodymanics, Optics, and Special Relativity</td>
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<td>Electrical and Computer Engineering 101A—Engineering Electromagnetics</td>
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<td>Materials Science and Engineering 90L—Physical Measurement in Materials Engineering</td>
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<td>Materials Science and Engineering 122—Principles of Electronic Materials Processing</td>
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<td>Mathematics 31A—Linear Algebra and Applications</td>
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<tr>
<td>3rd</td>
<td>Civil and Environmental Engineering M20 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)</td>
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<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits</td>
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<td>Mathematics 318 (Differential Equations) or Mechanical and Aerospace Engineering 82 (Mathematics of Engineering)</td>
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### Junior Year

<table>
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<td>1st</td>
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<tr>
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<td>Materials Science and Engineering 130—Phase Relations in Solids</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials</td>
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<td>Technical Breadth Course</td>
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<td>2nd</td>
<td>Materials Science and Engineering 120 (Physics of Materials)</td>
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<td>Materials Science and Engineering 131/13L—Diffusion and Diffusion-Controlled Reactions/Laboratory</td>
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<td>UCLA Samueli GE Elective</td>
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<tr>
<td>3rd</td>
<td>Materials Science and Engineering 121/121L—Materials Science of Semiconductors/Laboratory</td>
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<td>Materials Science and Engineering 132—Structures and Properties of Metallic Alloys</td>
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<tr>
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### Senior Year

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 121B—Principles of Semiconductor Device Design</td>
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<td>Technical Breadth Course</td>
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<tr>
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<td>UCLA Samueli GE Elective</td>
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<tr>
<td></td>
<td>Upper-Division Mathematics Course</td>
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<tr>
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<td>Electronic Materials Elective (Materials Science and Engineering 150—Introduction to Polymers or 160—Introduction to Ceramics and Glasses)</td>
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<tr>
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<td>Materials Science and Engineering 140A—Materials Selection and Engineering Design A</td>
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<td>Technical Breadth Course</td>
<td>4</td>
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<tr>
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<td>UCLA Samueli Ethics Course</td>
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<tr>
<td>3rd</td>
<td>Electronic Materials Elective</td>
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<tr>
<td></td>
<td>Electronic Materials Laboratory Course</td>
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<tr>
<td></td>
<td>Materials Science and Engineering 140B—Materials Selection and Engineering Design B</td>
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</tr>
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<td>UCLA Samueli GE Elective</td>
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**Total Units:** 182

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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 pages 22 and 23 for details).
4. See counselor in 6426 Boelter Hall for details.
5. See page 103 for list of approved mathematics courses.
## B.S. in Mechanical Engineering Curriculum

### FRESHMAN YEAR

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Courses</th>
<th>Units</th>
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<tbody>
<tr>
<td>1st</td>
<td>Chemistry and Biochemistry 20A—Chemical Structure(^1)</td>
<td>4</td>
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<tr>
<td></td>
<td>English Composition 3—English Composition, Rhetoric, and Language</td>
<td>5</td>
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<tr>
<td></td>
<td>Mathematics 31A—Differential and Integral Calculus(^1)</td>
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<tr>
<td>2nd</td>
<td>Chemistry and Biochemistry 20B/20L—Chemical Energetics and Change/General Chemistry Laboratory(^1)</td>
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<tr>
<td></td>
<td>Mathematics 31B—Integration and Infinite Series(^1)</td>
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<tr>
<td></td>
<td>Physics 1A—Mechanics(^3)</td>
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<tr>
<td>3rd</td>
<td>Mathematics 32A—Calculus of Several Variables(^1)</td>
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<tr>
<td></td>
<td>Physics 1B/4B—Oscillations, Waves, Electric and Magnetic Fields/Mechanics Laboratory(^1)</td>
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</table>

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<tr>
<td>1st</td>
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<tr>
<td></td>
<td>Mathematics 32B—Calculus of Several Variables(^1)</td>
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<tr>
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<td>Physics 1C/4B—Electrodynamics, Optics, and Special Relativity/Electricity and Magnetism Laboratory(^1)</td>
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<tr>
<td>2nd</td>
<td>Mathematics 33A—Linear Algebra and Applications(^1)</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 94—Introduction to Computer-Aided Design and Drafting(^2)</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 101—Statics and Strength of Materials(^2)</td>
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<tr>
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<td>Mechanical and Aerospace Engineering 105A—Introduction to Engineering Thermodynamics(^2)</td>
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<tr>
<td>3rd</td>
<td>Mechanical and Aerospace Engineering M20 (Intro to Computer Programming with MATLAB) or Computer Science 31 (Intro to Computer Science I)(^2)</td>
<td>4</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 82—Mathematics of Engineering(^2)</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 102—Dynamics of Particles and Rigid Bodies(^2)</td>
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<td>Mechanical and Aerospace Engineering 103—Elementary Fluid Mechanics(^2)</td>
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### JUNIOR YEAR

<table>
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<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 100—Electrical and Electronic Circuits(^2)</td>
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<td>Mechanical and Aerospace Engineering 156A—Advanced Strength of Materials(^2)</td>
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<td>Mechanical and Aerospace Engineering 183A (Intro to Manufacturing Processes) or 183B (Intro to Microscale and Nanoscale Manufacturing)(^9)</td>
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<td>Mechanical and Aerospace Engineering 105D—Transport Phenomena(^2)</td>
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<td>Mechanical and Aerospace Engineering 107—Introduction to Modeling and Analysis of Dynamic Systems(^8)</td>
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<tr>
<td></td>
<td>UCLA Samuels GE Elective(^5)</td>
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<tr>
<td>3rd</td>
<td>Mechanical and Aerospace Engineering 131A (Intermediate Heat Transfer) or 133A (Engineering Thermodynamics)(^3)</td>
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<td></td>
<td>Mechanical and Aerospace Engineering 157—Basic Mechanical and Aerospace Engineering Laboratory(^2)</td>
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<tr>
<td></td>
<td>Mechanical and Aerospace Engineering 162A—Introduction to Mechanics and Mechanical Systems(^2)</td>
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<td></td>
<td>Technical Breadth Course(^5)</td>
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### SENIOR YEAR

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<tr>
<td>1st</td>
<td>Electrical and Computer Engineering 110L—Circuit Measurements Laboratory(^2)</td>
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<td>Mechanical and Aerospace Engineering 171A—Introduction to Feedback and Control Systems(^2)</td>
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<td>Technical Breadth Course(^5)</td>
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<td>UCLA Samuels GE Elective(^5)</td>
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<tr>
<td>2nd</td>
<td>Mechanical and Aerospace Engineering 162D—Mechanical Engineering Design(^2)</td>
<td>4</td>
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<td>Mechanical Engineering Elective(^2)</td>
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</tr>
<tr>
<td></td>
<td>Technical Breadth Course(^5)</td>
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<td></td>
<td>UCLA Samuels GE Elective(^5)</td>
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<tr>
<td>3rd</td>
<td>Mechanical and Aerospace Engineering 162E—Mechanical Engineering Design(^2)</td>
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<td>Mechanical Engineering Elective(^2)</td>
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<tr>
<td></td>
<td>UCLA Samuels GE Elective(^5)</td>
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</tbody>
</table>

**TOTAL**                                                                                       **181**

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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 pages 22 and 23 for details).
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